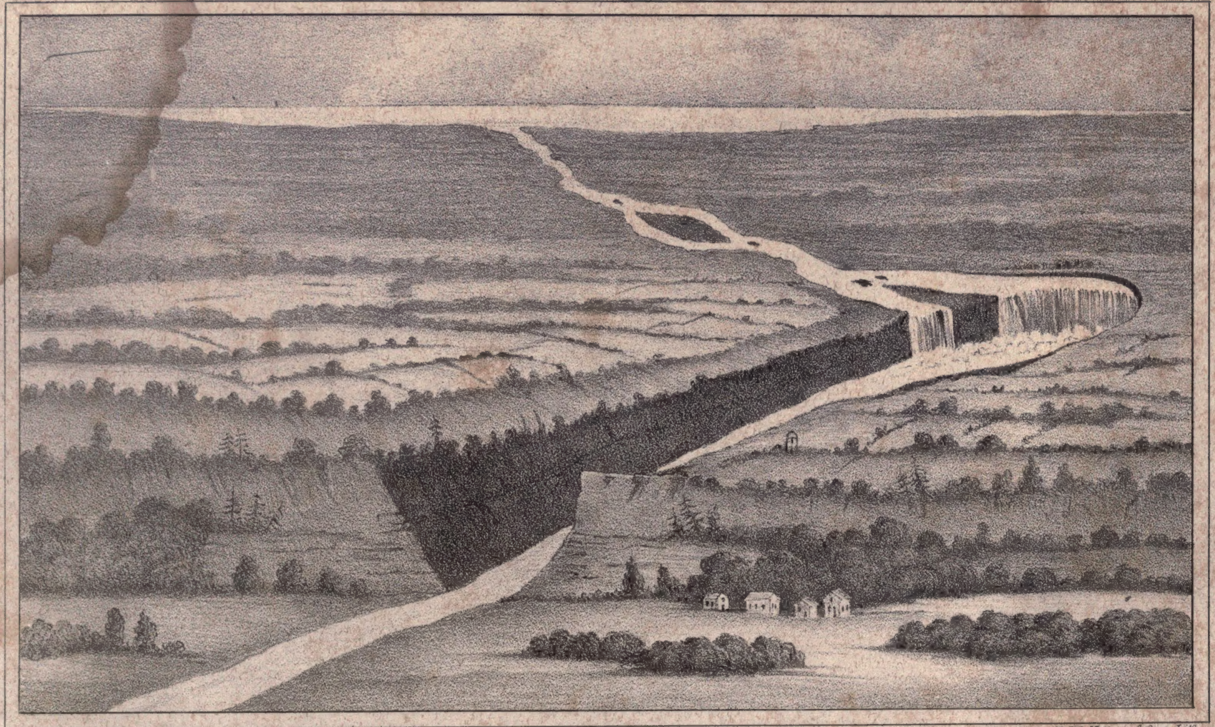


R. Bakewell Junr. D.W. Kellogg & Co's. Lith.

A Bird's Eye View or Map of the Country from Lake Erie to Queenstown;
exhibiting the Chasm formed by the retrograde movement of the Falls of Niagara.

AN

INTRODUCTION

TO

GEOLOGY:

INTENDED TO CONVEY

A PRACTICAL KNOWLEDGE OF THE SCIENCE,

AND COMPRISING

THE MOST IMPORTANT RECENT DISCOVERIES;

WITH EXPLANATIONS OF

THE FACTS AND PHENOMENA

WHICH SERVE TO CONFIRM OR INVALIDATE VARIOUS GEOLOGICAL THEORIES.

BY ROBERT BAKEWELL.

THIRD AMERICAN FROM THE FIFTH LONDON EDITION,
EDITED, WITH AN APPENDIX, BY
PROF. B. SILLIMAN, YALE COLLEGE.

NEW HAVEN:
B. & W. NOYES.
1839.

Printed by B. L. Hamlen.

PREFACE TO THE FIFTH EDITION.

THE additional facts and observations introduced into various parts of the present edition, together with several new cuts and sections, and one new chapter, have considerably increased its size, but the price will remain the same as that of the fourth edition.

The new Chapter, Nine, relates to a general fact, which has hitherto almost escaped the attention of geologists:—"On the removal and disappearance of coal strata, raised above the surface of the ground by faults, and on the probable causes of this removal." Whether the causes assigned by the author shall be deemed satisfactory or otherwise, he trusts he has rendered a useful service to geology, by directing the attention of inquirers to the subject.

On re-examining with attention the first edition of this work published twenty-five years since, (1813,) the author has felt satisfaction in observing, that many of his opinions in geology, which were then new, have been proved to be correct, by subsequent discoveries. He has been more particularly gratified by finding, that his anticipations of the agency of voltaic electricity, in the formation of metallic ores, and his suggestions that the different electrical conditions of adjacent rocks, contributed to the separation and deposition of metalic matter in veins, appear to have received a full confirmation, by the interesting experiments of Mr. Crosse. What the author stated on this subject in the edition of 1813, has been republished, verbatim, in all the subsequent editions, and is given in the present volume, pp. 356, 377; to which, and the observations, pp. 361, 362, he refers the reader.

In the preface to the fourth edition of this work, it was stated, that endeavors were made by some continental conchologists, to

establish the doctrine, that fossil conchology, independent of the succession and stratification of rocks, is the true basis of geology. In this country, attempts to divert geology from its proper object, appear to be in some instances progressive. In order to enhance the value of organic remains, it has been said, that the mineral covering of the globe is the mere brick and mortar of the edifice, and of course entitled to little consideration; and in a definition of geology, given in an ingenious and popular work, the knowledge of the mineral composition, and arrangement of the rocks and strata is omitted, and the science is limited to "*the investigation of the changes that have taken place in the organic and inorganic kingdoms of nature, and their causes.* (See note, p. 3.)

The author believes, that this is what the Germans call a one-sided view of the science, and he ventures to maintain, that the principal object of geology is to investigate the composition and contents of different rocks or strata, together with their position and arrangement, and their order of succession. Without this knowledge, we can obtain no satisfactory information whatever, respecting the former changes which the surface of the earth has undergone.

This may be made obvious to any person of sound understanding, whether he be a geologist or not. Suppose him to pass near the steep escarpment of a hill or cliff, in which the strata are distinctly exposed to view, and that their position was highly inclined or nearly vertical. If he examined them closely, he might find some of the strata composed of clay more or less indurated, others of sand and sandstone, and among these he might observe strata containing rounded or water-worn pebbles, and some beds with oyster shells, or other species of aquatic shells. A little reflection would convince him, that these beds had been deposited under water, like the beds of mud or sand in seas or lakes. If such was their mode of formation, they must originally have been deposited in a position nearly horizontal, but the strata he is examining are now nearly vertical; hence he is assured, that their position has been changed since their deposition. Thus, by a knowledge of the composition of the beds, and their arrangement in a vertical position, he discovers two important geological events, which he could not otherwise have ascertained. In almost all

descriptions, in which it is attempted to demonstrate the former changes of the earth's surface, the evidence, to be of any value, must be supported by references to the present structure and arrangement of the mineral crust of the globe; this forms the basis of all sound geological inductions. Fossil organic remains, however interesting to the botanist or zoölogist, are chiefly valuable to the geologist, by enabling him to trace the succession of distant beds where their continuity is interrupted, and also to discover the alternations from marine to fresh water formations, and in some instances, they serve to indicate the former condition and temperature of the earth.

The changes of the earth's surface, which take place during the short interval of one generation, are seldom of sufficient magnitude to effect any distinguishable alteration in the physical outline of a country; but by connecting these changes with those, which the investigation of the structure of the crust of the earth, proves to have taken place in remote ages, we are enabled to unroll some pages of the volume of nature, that disclose a portion of the ancient history of the globe.

The investigation of the past changes which the earth has undergone, forms a valuable branch of the science of geology; the chapters relating chiefly to this subject, are placed in the latter part of the present edition, and are separated from the preceding chapters by a distinct title page, and a brief notice.

Hampstead, near London, March 29, 1838.

Part of Prof. Silliman's Preface to the American reprint of the Third and Fourth Editions, with a few verbal alterations.

The Editor believes that he is performing a service to his country, by encouraging the republication of a work conspicuous for attractiveness and perspicuity, and for a style generally correct and vigorous,—often eloquent and beautiful. The author is distinguished by great independence of spirit, which carries him straight to his object, without any servile regard to previous systems. His theoretical views appear to be generally philosophical and just, and some of them are peculiarly happy.

Speaking in the character of a public instructor of youth, I beg leave to add, that my immediate motive for recommending the republication was, that I might place in the hands of my own classes, a comprehensive Treatise on Geology, which they would be willing to read and able to understand.

PREFACE TO THE FOURTH EDITION.

THE present volume contains above one fourth more letter-press than the third edition: being printed closer, and in a fuller page, in order to comprise numerous additional facts, and the important discoveries recently made in geology. There are five entirely new chapters, beside considerable additions to most of the former chapters.

Since the publication of the third edition, the author has revisited several of the localities which were the scenes of his earliest investigations; he has also examined certain parts of England, of which the geology was dubious; and has inserted in this work such alterations as were deemed necessary. These, however, bear a small proportion to the valuable labors of foreign and English geologists, during the last five years, of which an account is given in different parts of the volume. In a preliminary dissertation, on certain living species of animals that elucidate fossil conchology, and also in the work itself, the author has endeavored to direct the attention of geological students to a subject hitherto much neglected. Great importance is attached to the study of fossil shells; but the character of the animals that inhabited them, or the power they might possess of modifying the form of the shell under various circumstances, has scarcely been thought of. Some French conchologists are endeavoring to establish the doctrine, that fossil conchology, independent of the succession and stratification of rocks, is the only true basis of geology; and a trifling difference in the form of a shell, is deemed sufficient to constitute a new species, and to warrant the most important conclusions respecting the age of rock formations.

If the same conchologists were interrogated, respecting the power which the ancient inhabitant of the shell might possess, of changing its structure when placed in different circumstances, they would be compelled to confess their ignorance. A knowledge of fossil shells is highly useful to the geologist, in cases

where the superposition of strata cannot be ascertained; but fossil shells alone, give us less positive information respecting the ancient condition of the globe, than the organic remains of other classes of animals, or of vegetables; because, for any thing we know to the contrary, all the species of molluscous animals that inhabited these shells, *may have been capable* of living in the same medium, and under the same conditions. But different species of vertebrated animals and plants, must have existed under very different conditions on land or in water. M. Boué, an enlightened and indefatigable continental geologist, to whose labors the science is greatly indebted, is meritoriously endeavoring to resist the absurd attempt, to force fossil conchology into the chair of geology. I trust his example will be followed by English geologists. Indeed, I am convinced that many of the frivolous distinctions introduced by conchologists will soon pass away, as those of mineralogy have already passed; and that these two branches of natural history, will take their proper stations, as auxiliaries subservient to geology.

It will be seen, by the titles to the new chapters in the present volume, that they comprise various subjects connected with important inquiries relating to the theory of the earth. The opinions of the author have not been rashly advanced, to oppose or maintain the systems of other geologists: they are the result of long-continued reflection, on what appeared to him the most probable explanations of geological phenomena. The author says *probable*, because he considers that the words truth and certainty cannot yet be introduced with advantage into geological theories.

The third edition of this work was republished in America, in 1829, by Professor Silliman, of Yale College, Connecticut, the distinguished editor of the *American Journal of Science.* It was commenced without any previous communication or acquaintance with the author. The author will be satisfied if the present work should be thought deserving of the commendation given by the American editor, of being "a comprehensive Treatise on Geology, which the student will be willing to read, and able to understand."

Hampstead, near London, April 18, 1833.

PREFACE TO THE THIRD EDITION.

The first and second editions of the *Introduction to Geology* were favorably received, and sold off soon after their publication. The work has since been translated and published in Germany, by Mr. Frederick Muller, of Friburg; but it has been long out of print in this country. The causes which have retarded the publication of a third edition it is unnecessary to mention: the delay has, I trust, been favorable to its appearance in a very improved state; as I have been collecting materials for it, during several years, having visited almost every situation of much geological interest in our own island, from the Land's End in Cornwall, to the Grampian Mountains in Scotland; and passed part of three years in examining the geology of Savoy, Switzerland, and France. There is scarcely a rock formation described in the present volume, that I have not examined in its native situation, and compared with the descriptions of former geologists. I have also had opportunities of examining the collections, and of profiting by the communications, of some of the most eminent geologists on the continent.

While engaged in these pursuits, I have not been inattentive to the labors of other observers. So numerous and interesting are the discoveries made in geology during the last ten years, that, in order to present a concise view of the science in its present advanced state, the *Introduction to Geology* has been recomposed and all the chapters are greatly enlarged.

The following new chapters have been added:—On Fossil Organic Remains. On the Principles of Stratification. A Retrospective View of Geological Facts. On the Destruction of Mountains; and on the Bones of Land Quadrupeds, found in Diluvial Depositions and in Caverns. On the Formation of Valleys; and on Deluges and Denudations.—The Plates are new, except Plate IV, and part of Plate VII.

The Outline Map of the Geology of England and Wales, was, I believe, when published in the first edition of 1813, the only geological map of England that had then appeared. It presents in one view the grand geological divisions of the country, without delineating the different strata in each division. It was thought that the publication of this map in its original form, (or nearly so,) would be acceptable to those who wished to gain a general knowledge of the geology of their own country, without entering into geological details.

In the course of the present work, I have frequently attempted to elucidate the geology of England, by comparisons with situations I have examined on the continent, in order to connect the geology of our own island, with that of France, Switzerland, and Savoy. By comprising the numerous facts and observations contained in the present volume, within the limits of an elementary work, from the desire to be concise, I may have run the risk of becoming obscure: this I have studiously endeavored to avoid.

For any errors into which I may have inadvertently fallen, I would claim the candid indulgence of the reader, in the last words of that distinguished geologist, Horace Benedict de Saussure, "*On peut être utile, sans atteindre à la perfection.*"

Hampstead, near London, March 10, 1828.

PREFACES TO THE

FIRST AND SECOND EDITIONS, IN 1813 AND 1815, ABRIDGED.

In tracing the progress of knowledge, we may frequently observe that the cultivation of particular branches of science, at certain periods, was determined by causes which had little connection with their intrinsic utility. Fashion, caprice, and the authority of eminent names, govern mankind in philosophy, as well as on all other subjects. But, independently of accidental causes, there are leading objects in the universe, which, as nations advance in civilization, seem naturally to direct their attention to certain sciences in succession. The brilliancy of the sun, moon, and planets, their various motions, and connection with the changing seasons, would first arrest the attention of the rude philosopher; nor need we wonder that he soon began to regard them as endowed with life and intelligence, and attributed to them a mysterious power over human affairs: thus the heavenly orbs became the objects of religious adoration; and curiosity, hope, and fear lent their aid to the early cultivation of astronomy.

Mathematics and mechanical philosophy are so intimately connected with astronomy and the useful arts, that they naturally claimed the second place among the early sciences.

The branches of philosophy which comprise a knowledge of the physical qualities of matter, or such as are perceptible by the senses, follow next; and at a later period, chemical philosophy, or that science which endeavors to ascertain the elementary substances, of which all material objects are composed. In the order of succession, mineralogy and geology are the last of the natural sciences; for though an acquaintance with the earth is more important to man, than a knowledge of the distant parts of the universe, yet, previously to the cultivation of the other sciences, and of chemistry in particular, our knowledge of the mineral

kingdom could not extend much beyond that of the rudest periods. Thus we find, that notwithstanding the precious metals, and many of the mineral treasures which the earth contains, have been the objects of insatiable cupidity in every age, yet, till the present day, almost all that was known of mineralogy was confined to uneducated working miners.

In looking over the pages of history we may observe, that the most polished nations of antiquity had scarcely advanced beyond a limited acquaintance with astronomy, geometry, and mechanical philosophy. In modern Europe, all the natural sciences, geology and mineralogy excepted, have been successfully cultivated, and their progress has been astonishingly rapid; but till about the middle of the last century, the structure of the earth had scarcely engaged the attention of philosophers. Near that time, Lehman, the German, first observed that there are certain rocks which occupy the lowest relative situation in different countries, and that these rocks contain no organic remains: hence he gave them the name of primary, and established a division between them and the rocks by which they are covered, in which the remains of animals or vegetables frequently occur: the latter he called secondary. In our own country, the Reverend J. Michell was the first person who appears to have had any clear views respecting the structure of the external parts of the earth: they were made public in a valuable paper on the cause of earthquakes, in the Philosophical Transactions, 1759. About twenty years afterwards, Mr. John Whitehurst published his "Inquiry into the original State and Formation of the Earth." His observations were principally confined to the rocks and strata of Derbyshire. Independently of its speculative opinions, this work was highly valuable as an attempt to describe the geology of a district, from actual examination. The great variety of original information it contained, and its general accuracy, will remain a lasting monument of the writer's industry and ability. Mr. Whitehurst, however, fell into the same error with the celebrated Werner, in Saxony, an error to which the first cultivators of geology were particularly exposed,—that of drawing general conclusions from local observations, and forming universal theories from a limited number of facts.

Though Mr. Whitehurst's book was favorably received, yet till the beginning of the present century geological pursuits made little progress in England. On the continent, the researches of Saussure, Pallas, Werner, St. Fond, Dolomieu, and others, had before this time produced a powerful interest, and brought into the field many active and enlightened inquirers. The first general impulse given to the public taste, for geological investigations in this country, was produced by Professor Playfair's luminous and eloquent illustrations of the Huttonian theory. The leading feature of this theory, that all rocks or strata have been either formed or consolidated by central subterranean fire, was very warmly opposed; and much personal animosity and many adventitious circumstances were associated with the contest, not highly honorable to philosophy, but well calculated to keep alive the attention of the disputants to those appearances in nature, which favored or opposed their different theories.

He who attempts to make a scientific subject familiar, runs the risk, in this country, of being deemed superficial: a plentiful share of dullness, combined with a certain degree of technical precision, is regarded as essential proof of profundity. By prescriptive right, long established in these realms, dullness and pedantry guard the portals of the temple of Science, and command those who enter, to avert their eyes from whatever can elevate the imagination, or warm the heart, and to look at nature through a sheet of ice. In compliance with their authority, writers of introductory treatises have generally thought it necessary to avoid that felicity in the familiar illustration of scientific subjects, so conspicuous in some of the elementary works of our neighbors. Without venturing to depart too far from established usage, I have endeavored to render geology more intelligible, by avoiding as much as possible, theoretical and technical language, and by introducing a simple arrangement, suited to the present state of our knowledge. The local illustrations from various parts of our island, with the drawings, sections, and map in the present volume, will, I trust, facilitate the study of geology, and prove particularly acceptable to those who are entering on these inquiries: at the same time, I flatter myself with the hope, that the original information this work contains, respecting the geology and natu-

ral history of England, will secure it a candid reception.—*Edition of* 1813.

Several have been deterred from the study of geology by the supposed difficulty of learning its attendant science, mineralogy: but an acquaintance with the nice distinctions made by many modern mineralogists, is not necessary to gain a knowledge of the structure and arrangement of the great masses of matter that environ the globe, nor of the substances of which they are composed. He who would gain a useful knowledge of geology, would do well to provide himself with specimens of common rocks, and the simple minerals of which they are composed, and examine their external characters and physical properties, comparing them with the descriptions given by the best mineralogical writers. Fortunately these substances are not very numerous, and he may (without present inconvenience) omit the more rare crystallizations and varieties, so much valued by cabinet philosophers; for here, as in many other instances, the received value is in an inverse ratio of the utility. The pedantic nomenclature, and frivolous distinctions recently introduced into mineralogy, may gratify vanity with a parade of knowledge; but they are unconnected with objects of real utility, or with any enlarged views of nature.

On hearing the various names which mineralogists give to the same substance, and observing the avidity with which each new name is seized, as if it conveyed a hidden charm, the uninitiated might suppose that he was "journeying in the land of Shinar," and had fallen in company with a set of masons fresh from the tower of Babel, each one calling the same stone by a different name, and glorying in his absurdity. Such frivolities disgust men of sense with the study of an important and interesting science; a science that has for its immediate object the structure of the planet which the Author of nature has destined for our abode, and an acquaintance with the situation of its various mineral productions, subservient to the wants or enjoyments of man in civilized society.

The advice of Cicero to the cultivators of moral science, applies with peculiar force to the geologists and mineralogists of the present day. "In these natural and laudable pursuits, two errors

are particularly to be avoided: the first, not to confound those things of which we are ignorant with those we know, or rashly to yield our assent without due investigation; the second, not to bestow too much labor and study on obscure, intricate and unprofitable subjects."—"In hoc genere et naturali et honesto duo vitia vitanda sunt: unum, ne incognita pro cognitis habeamus, hisque temere assentiamur (quod vitium effugere qui volet, adhibebit ad considerandas res et tempus et diligentiam.) Alterum est vitium, quod quidam nimis magnum studium multamque operam in res obscuras atque difficiles conferunt, easdemque non necessarias."—*Cic. Offic.* i. 6.

CONTENTS.

CHAPTER IV.

ON STRATIFICATION, AND THE RELATIVE POSITION OF ROCKS.

CHAPTER V.

ON ROCKS DENOMINATED PRIMARY, AND THE CHANGES TO WHICH THEY HAVE BEEN SUBJECTED.

CHAPTER VI.

ON GNEISS AND MICA SLATE, AND THE ROCKS WHICH ARE ASSOCIATED WITH THEM.

CHAPTER VII.

ON TRANSITION ROCKS, AND ON THE PROBABLE CONDITION OF THE SURFACE OF OUR PLANET DURING THE TRANSITION EPOCH.

DESCRIPTION OF THE PLATES.

The Frontispiece is a bird's-eye view of the river that descends from the Falls of Niagara to where it issues from the channel which it has excavated, into the plain at Queenston. The distant country extending to Lake Erie is introduced, to represent the physical structure of the country. See p. 260. The plate is taken from a sketch drawn near Queenston, in 1829, by Robert Bakewell, junior.

Plate I.

Figs. 1, 2, 3, 4, 5, 6. Illustrations of plane and curved stratification. (See Chapter IV.)

Plate II.

Fig. 1. Overlapping strata with straight edges.

Fig. 5. Overlapping strata with curved edges.

Fig. 2. Structure of a part of the Alps, representing the beds, nearly vertical, that approach the central range, and the bended stratification of the outer ranges. The dotted lines represent the supposed extension of the beds at the period of their elevation; *d d*, granite and mica-slate; *c c*, beds of soft slate; *b a*, *b a a*, beds of secondary limestone, sandstone, and conglomerate; *x y z* represent the arched stratification of the outer ranges.

Fig. 4. A section representing the arrangement of the rocks and strata at Charnwood Forest, in Leicestershire, from the manor of Whitwick, to near Barrow-on-Soar. In this section the proportions of distance are disregarded, in order to bring the different rock formations within the space of the plate. *a a a*, stratified red sandstone; *b b*, rocks of granite, sienite, and porphyry; *c c*, slate-rocks of Swithland quarry, the beds much elevated; *d d*, coal strata, rising towards the granitic and slate-rocks; *e*, lias, covering the red marl at Barrow: the elevated strata out of the line of Section on the left hand side of the plate, represent limestone rocks of Clouds Hill and Breedon. It is obvious from this arrangement, that the strata of sandstone *a a a* were deposited upon the slate-rocks and granite, after the beds had been raised into their present position: whereas in fig. 2, the beds *a a* have evidently been deposited before the beds of granite in the Alps were elevated; and as these beds *a a*, *b a b*, are of more recent formation than the sandstone *a a* in fig. 4, their position proves decidedly, that the beds of granite in the Alps were elevated after the beds of granite and slate in Leicestershire. (See chap. XXIII.)

Fig. 3. A granite vein in slate.

Fig. 6. The remaining portion of a thick bed of limestone, forming an isolated mass *b* on a mountain in Savoy. *a a*, the former extent of the bed; *c c*, a bed of soft sandstone.

Plate III.

Fig. 1. The conformable position of rocks. *a*, granite; *b*, gneiss; *c*, mica-slate; *d d*, slate; *x x*, a subordinate bed of limestone in slate; 2, a bed of conglomerate; *e e*, transition limestone and greywacke; F F, coal strata.

Fig. 2. A, unconformable massive rocks; a thick bed of porphyry or basalt C C, covering the transition rocks 1, 2, 3, and dykes of porphyry or basalt intersecting transition rocks.—N. B. The Porphyry at Christiania, in Norway, occurs in this position; the lower part of it is amygdaloidal basalt; the middle part is porphyritic, which passes in the upper to beautiful sienite and common granite. (See page 162.) The rocks B, on the right, represent the three modes of basalt: a columnar bed *d*, with a vertical dyke of basalt, and beds of interposed basalt; *b* is an isolated cap of columnar basalt.

Fig. 3. Unconformable strata of sandstone, covering coal strata on the side of the dip B, and on the side of the rise D. (See page 133.)

Fig. 4. A section of the strata near Dudley, Staffordshire. A, Wren's Nest Hill; the two beds of limestone are folded round the hill, as represented in the small compartment B, which is an horizontal section of the two beds of limestone *a*, *b;* the thirty feet bed of Staffordshire coal C is seen cropping out near the foot of Wren's Nest Hill; B, the arrangement of the limestone strata at Dudley Castle Hill; D, a hill capped with basalt. In this section the proportion of distance has been disregarded, for the same reason as in Plate II, fig. 4.

Plate IV.

Fig. 1. Arrangement of the strata from Sheffield, in Yorkshire, to Castleton, in Derbyshire,

Fig. 2. Coal strata, arranged in basin-shaped concavities, and intersected by a fault.

Fig. 3. Coal strata thrown up by a broad dyke. (See Chap. VIII.)

Fig. 4. Coal strata intersected by faults at different epochs.

Fig. 5. Metallic veins in limestone, cut through by toadstone.

Plate V.

The gigantic Trilobite, and two smaller species.

Plate VI.

Map of the geology of England and Wales, and a section of the Vale of Thames.

Plate VII.

A section of England through Durham and Cumberland; a group of columnar trap rocks, Cader Idris; ground plans of metallic veins, &c.

Plate VIII.

Living illustrations of fossil conchology:

Fig. 1. Cuttle-fish, or Sepia.

2. Beak of a Calmar.
3. The Nautilus Pompilius and its shell.
4. A Scaphite.
5. A Hamite.

CUTS AND SECTIONS.

PRELIMINARY OBSERVATIONS,

ON THE OBJECTS CONTAINED IN PLATE VIII, ENTITLED "LIVING ILLUSTRATIONS OF FOSSIL CONCHOLOGY," WITH REMARKS ON THE GROWTH OF CHAMBERED SHELLS, AND ON THE EXISTENCE OF ANIMAL LIFE AT GREAT DEPTHS IN THE OCEAN.

MAN, when he becomes the historian of the animal kingdom, generally considers his own structure as a type of the most perfect organization; and regards those animals that depart the most from this type, and have the smallest number of senses, as the least perfect. Strictly speaking, every animal is perfect, that is, so organized as to answer the purposes for which it was created; yet with reference to ourselves, we may, without much impropriety of language, call those animals which have the smallest number of senses and organs, the most imperfect. The very earliest inhabitants of the ancient world appear chiefly to have belonged to those orders of animals, that had little power of locomotion, and few organs of sense: many of them were without heads or eyes, and were, like the oyster, confined in shells, which they could merely open and close. Of these there were such immense multitudes, that calcareous mountains of vast magnitude and extent, are sometimes chiefly composed of their remains.

From what we see of the present animal creation, we have reason to believe, that creatures of every species, when free, and provided with the aliment they require, derive pleasure from the very action of their organs, and from existence itself. Of the kind or extent of the happiness enjoyed by a creature enveloped in darkness, and without head, heart, or eyes, or the power of removing its habitation, we can, however, form no idea; yet for any thing we know to the contrary, the inhabitant of a bivalve shell, may be far happier, than the monk immured in his stony cell, or than other individuals of the highest order—Man—who, however perfect their physical organization, make but little use of the intellectual and moral faculties, figuratively called the head and the heart.

Dr. Paley, in his "Natural Theology," has some beautiful reflections on the apparent happiness enjoyed by shoals of young shrimps, that were bounding into the air from the shallow margin of the water, or from wet sand. He observes: "If any motion of a mute animal could express delight, it was this." We cannot take cognizance of the actions of creatures enclosed in bivalve shells; but a distinguished philosopher was so fully convinced of the happiness enjoyed by testaceous animals, that he calls calcareous mountains, filled with their remains, "monuments of the felicity of past ages."

Beside the animal remains visible in calcareous mountains, they contain countless myriads of minute shells, which can only be discovered by the microscope. In a few specimens of chalk examined by Mr. Lonsdale, he ascertained among a multitude of these shells, a great variety of distinct species. The coral islands and reefs in tropical climates are entirely formed by animal secretion, and it is probable that many ancient çalcareous formations have had a similar origin.

It is with a view to excite the curiosity of the geological student, and to direct his attention to something beside the external form of shells, that I offer the following observations.

The reader who is entirely unacquainted with conchology, may form some general idea of a shell, if he be told that it is a univalve, like a snail or a perriwinkle; or a bivalve, like the muscle or cockle.

There are, however, numerous fossil bodies classed with shells, of which the general reader can form no notion whatever from the names;—such are the orthoceratite, the scaphite, &c. These are called chambered cells, from their being divided by partitions into numerous cells, or chambers; a tube, called a siphunculus, passes through the whole series of chambers.

Till within the last few years, these chambered shells have been considered as the habitation of marine animals, like the bivalve and univalve shells; but a little reflection may convince us, that the chambers in most of these shells were much too small to contain the animal, nor could the animal possibly pass from one chamber to another. There is, however, one living species, in which the outward cell or chamber is so much larger than the rest, that there is sufficient space to contain a great part of the animal. This is the nautilus pompilius, an inhabitant of the Indian Ocean. See Plate VIII, fig. 3, taken from a drawing by Mr. Owen, which represents the animal collapsed in the last, or open chamber of the shell.

The animals belonging to the different chambered shells are called by Cuvier, Cephalopodes, because the organs of motion are placed round the head, and they walk with their heads downwards. The living species of cephalopodes, are for the most part without any external shell; but some have an internal hard substance without chambers, of which the cuttle-fish bone affords a familiar example. This is taken out of the body or sac of the animal—the sepia officinalis, which is common on our coasts.

The general character of the cephalopodes, as given by Cuvier in his *Règne Animal*, tom. iii, is, "that the mantle or cloak is united under the body of the animal, and forms a muscular sac, which envelopes all the viscera. The head projects from the opening of the sac; it is round, and has two large eyes, and is surrounded (*couronnée*) by fleshy arms or feet, which are conical, and vary in length in different species. These arms bend in every direction, and are exceedingly powerful. On the surface of these arms are numerous suckers, by which the animal fixes itself strongly to the bodies that it seizes and enfolds. These arms serve the animal both to seize its prey, to walk, or to swim. It walks in every direction, having the head below, and the body above. At the base of the arms is the mouth, which is provided with two strong jaws resembling the beak of a parrot, and also with a fleshy gizzard like that of a bird. Most of these animals, when pursued, excrete a particular black liquor, which darkens the water, and conceals them from their enemies. There is a fleshy funnel placed near the neck, which serves the animal for its excretions, and also to eject the water that it absorbs for the purpose of respiration. They are of two sexes, and are voracious and cruel: as they have great agility in seizing their prey, they destroy multitudes of fish and crustaceous animals."

The Calmar. Mr. Needham, celebrated for his microscopic discoveries in the last century, paid particular attention to the structure and

habits of the calmar, off the coast of Portugal. The calmar, in all its essential parts, resembles the common sepia, but instead of the internal shell or bone of the sepia, it has a horny plate in its place. Mr. Needham says that the black liquor or ink which it ejects, is used for the purpose of blinding the animals on which it preys; they are chiefly pilchards. The annexed cut is reduced from Mr. Needham's figure of the calmar; it agrees with that of the animal of the spirula, as described by Lamarck, much better than the figure given by Blainville.

Into this figure I have introduced an outline of the shell of the spirula, like the shell on the right hand.* The shell of the spirula is as complex as that of the nautilus, but it is evident that its form and growth were the result of animal organization, and totally independent of the skill or volition of the animal, as much so as the vertebræ and bones of vertebrated animals. Now if we suppose the animal to be much larger, and to have within it a straight chambered shell, like the orthoceratite on the left hand, (which is sometimes three feet in length,) in this case we must also admit, that the shell was perfectly formed within the animal, before it issued from the egg, and grew with its growth. All the chambered

* Several bodies of molluscous animals, each containing a shell of the spirula, have been found near the Canary Islands. The shell is entirely internal, and the animal had fins and large eyes resembling the calmar. *L'Echo du Monde Savant*, *May*, 1836.

shells we are acquainted with (except the nautilus, and perhaps some species of ammonites) were internal, and grew independently of animal volition; and why naturalists should suppose that the nautilus constructs its own shell, making one chamber after another, I am utterly at a loss to conjecture. It appears to me a complete departure, without any reason, from what is known respecting the spirula, and what is admitted respecting all internal chambered shells. The siphuncle, beside its function of a float, so well explained by Dr. Buckland, is probably connected with a series of minute vessels, distributed through the shell, which are essential to its growth.*

Some of the cephalopodes with chambered shells, must have been very large, as there are ammonites two feet in diameter, and orthoceratites from two to three feet in length. Dr. Milne Edwards says, that there are living sepia in the Indian Ocean, from four to six feet in length. The flesh of the sepia was esteemed a great luxury by the ancients, and is now eaten by the fishermen in the Isle of Portland.

The nautilus pompilius, represented Plate VIII, fig. 3, is chiefly intended to show the position of the animal in the shell, a section of which is given, representing the interior chambers, and the siphunculus passing through them. The animal is less perfect in its organization than those species of sepia that are without external shells. It had ninety two arms or tentacula.† The nautilus is both recent and fossil.

Fig. 1. Plate VIII, is the SEPIA OCTOPEDIA, an inhabitant of the British seas; it differs from the calmar in the form of its body; the latter has fins and two feelers, much longer than the others, as represented in the above cut. Plate VIII, fig. 2, is the beak of the calmar.

SPIRULA.—If the figure of the animal containing the spirula, as given by Blainville from Perron, be not imaginary, there must be two animals, bearing similar shells, one of them resembling the calmar. The shell of the spirula, see Plate VIII, fig. 11, is nearly like that of the nautilus, but the whorls do not touch each other.‡

The AMMONITE (fig. 6,) of which there are numerous species, differs greatly from the chambered nautilus, the whorls or turns being all distinct, and in the same plane, and the cells are very small. The siphunculus is placed near the outer edge of the shell. In many species, the cells are divided by indented partitions, as represented in fig. 7; in other species the cells are undulated. Some ammonites in the vicinity of Bath, are eighteen inches or more in diameter. Ammonites, though so abundant in the secondary strata, have not been found in a recent state, except the account can be relied upon, of their having been discovered in the Pacific Ocean.

The SCAPHITE resembles an ammonite partly unrolled. A very remarkable specimen of one recently discovered in France is represented,

* The stony stem of the fossil encrinite, when suspended and dissolved in diluted muriatic acid, discloses a series of internal fibres or vessels, and it is probable that analogous fibres are distributed through all internal shells. Indeed, the nautilus is not entirely an external shell; a part of it is enveloped in the sac or mantle, as may be seen in Plate VIII, fig. 3.

† See observations on the difference between complexity of organization, and perfection of structure. Page 30.

‡ The animal that inhabits the thin open shell, called the paper nautilus, but more properly the argonaut, is also a species of sepia; it is common in the Mediterranean. It is very rarely found fossil.

fig. 4. It is not improbable, that many internal shells were composed rather of a corneous substance than of shell, and were capable of being coiled or folded by the will of the animal.

Fig. 8. The BACULITE is a straight chambered shell. The divisions are indented like those of the ammonite.

Fig. 12, the ORTHOCERATITE is a straight chambered shell, resembling the ammonite unrolled, but the cells are divided by concave partitions, as in the nautilus. Some orthoceratites are two or more feet in length; the animal that contained them must have been of vast size. Orthoceratites are the most ancient of fossil chambered shells, and are chiefly found in transition limestone.

The HAMITE, fig. 5, is bent like a hook, from which it takes its name; in other respects it resembles the baculite.

The LITUITE resembles the hamite, but the smaller end is coiled like the spirula.

Fig. 9, the BELEMNITE is a straight shell with an internal chambered cone. In perfect specimens, the topmost chambered shell is greatly enlarged, and forms a cup in which the ink bag was placed. See Buckland's B. T., vol. i, p. 371.

Fig. 10. The TURRILITE is a long spiral chambered shell, frequently found in the green sand of the Alps.

Fig. 13. The NUMMULITE (so called from its resemblance to a small Roman coin) has nearly a flat or lenticular form. It has within it a cavity, divided by partitions into numerous small cells, but without a syphon or siphunculus; part of the outside of the shell is removed in the figure, to show the internal chambered structure. This little fossil, forms entire calcareous hills and immense beds of building stone in some countries. "It is of stone composed of these shells that the Pyramids of Egypt are constructed."—Cuvier, *Règne Animal.*

The animal to which the shell of the nummulite belonged, was supposed to be a cephalopode, like the sepia, but according to Dr. Milne Edwards, the animal is found living in the Mediterranean sea, and is neither a cephalopode, nor any other genus of mollusca, but has a singular structure, which appears to approach to that of a polypus. *Elemens de Zoologie*, p. 787. From the number of cells or foramina in the nummulite, they have received from the French, the name of *Forameniferes.*

We come now to other orders of molluscous animals, whose organization is less complex, and their powers of motion more limited, than in the cephalopodes. These are the inhabitants of bivalve and univalve shells. The first are called by Cuvier Acephalous, being without heads. Of these the oyster offers the most familiar example. Most of the species are permanently attached to rocks, and have no member to protrude beyond the shell. Those species of the oyster family that are not attached permanently, can only move by driving out the water, as they suddenly shut the valves of the shell. Species of other genera of bivalves, though without heads, possess the power of locomotion.

Fig. 16, represents the animal and shell of a Bucardium.

This animal puts out a triangular body, formed of two pipes or tubes, separated and flat, but which become round as the water enters by the lower tube, and goes out at the upper one. The tubes are surrounded with hairs. When the animal is disturbed, or hears a noise, it throws out water to the distance of a foot. When it wishes to change its quar-

ters, it protrudes a long foot, and seeks, with the further end of it, some object or point of support, to which it fixes it; the animal then draws back its shell about two inches at a time, till it has attained or reached the spot where it desires to abide. Cuvier regards one of the tubes as suited for respiration by the absorption of water, and the other for its excretions. He further states, that bivalves which have these tubes, live buried in mud or sand.

The animals inhabiting univalve shells are chiefly classed by Cuvier as Gasteropodes, from their moving on their stomachs like snails. In most species of univalves, the animal has a head with two eyes, and a trunk resembling the trunk of an elephant; with this trunk it seizes its food; and in some species the trunk is used for piercing other shells. The animal crawls upon a fleshy foot, near the end of which there is a horny substance called an operculum, that serves as a door to close the shell, when the animal withdraws into it. In many species of univalves, the animal can fold the mantle so as to form a tube which protrudes into the water, while the head and foot remain in the shell. Some species of univalves are carnivorous, others are herbivorous, and the nature of their food determines their residence, either near the shore or in deep water.

Fig. 15, represents the shell and animal of a species of Buccinum, which agrees with the above description of the inhabitants of univalve shells. The foot on which it crawls is on the left hand, with the oval operculum near the end of it. On the right hand of the figure, at the top, the mantle is represented folded, to form a tube, as above described.

In some species, both of bivalve and univalve shells, the animals depart considerably from the general character of the class to which they belong. There are some bivalves which have the cavities of the shells divided by partitions, the uses of which are not known; and some univalves have an apparatus for swimming on the surface of the water.

The Hippurite, a remarkable fossil bivalve, with a deep conical under shell, and a flat lid, is represented fig. 14. It is classed by Cuvier with the oyster family; and by Parkinson, with chambered shells. The nature of the animal is unknown. The shell is divided by transverse septa, or partitions, on which account Mr. Parkinson places it among other species of chambered fossils. The existence of a lid seems to prove, that it was not an internal shell, but the habitation of the animal.

The Janthina is a beautiful purple colored univalve shell, nearly resembling in form the snail; Lamarck discovered, that it could not crawl on its foot, but that the foot is covered with air bladders, which enable the animal to rise and swim on the surface of the water. The janthina is common in the Mediterranean; when touched, it excretes a deep purple liquor, which tinges the surrounding water. (Cuvier, *R. A.* tom. iii.) There are other animals occupying univalve shells, that have the power of swimming. The Lymnea stagnalis, an inhabitant of ponds, swims on the surface of the water in a reversed position. It descends by compressing itself within the shell, and expelling the air, and thus sinks immediately to the bottom. Mr. Parkinson rightly conjectures, that the shells resembling the Helix, or snail, in the older strata, were constituted for swimming, like the janthina: they could scarcely have used a foot for crawling, at the bottom of a deep and agitated ocean.

We come now to another division of the animal kingdom, called by Cuvier, *Radiated*. See Chap. II. Some of the animals comprised in

this division have left abundant remains in the fossil state, particularly the encrinite and the pentacrinite. These animals had a stem, composed of numerous plates, and terminating in branches surrounding the mouth, resembling the stem and branches of a vegetable. Both the encrinite and pentacrinite were supposed to be extinct; but a living pentacrinus has been discovered in the West Indies, and a smaller species, more recently, in the Cove of Cork. This has been described by Mr. J. V. Thompson, of Cork. A drawing of this animal, taken by Mr. Thompson, is given. (Plate VIII, fig. 17.) A cut of a remarkable species of fossil encrinite is given, p. 275; it is named the Lily Encrinite, because the arms, when folded, resemble the head of the lily. Indeed, the whole class of encrinites, and pentacrinites, are called *crinoidea*, from *krinon*, the lily, by Mr. Millar, in his valuable work on these fossils. The arms of part of a Briarean pentacrinite are represented, p. 216.

In the encrinite, the stem is composed of numerous round plates, or vertebræ; the branches are also composed of numerous smaller, but similar plates, as may be seen by referring to fig. 17, and the cuts. The pentacrinite differed from the encrinite, by the plates or vertebræ of the stem and branches being pentagonal. The stems of both were attached to rocks. They appear, like various polypi, to have increased by throwing out lateral stems (see the above fig.) The calcareous vertebræ that formed the stem and branches, were enveloped by a thin coat of animal matter, which must have possessed great muscular power, to have enabled the animal to move its arms with facility, when seizing its prey.

In fig. 17, the expanded arms of the upper head of the pentacrinus, expose the pentagonal aperture or mouth in the centre; and a little above this is a round tube or aperture, which serves for the excretion of the fæces. In fig. 18, which is a head with the arms removed, it will be seen, that the excreting tube projects a little above the mouth. One head of the pentacrinus is represented as folded, and another as partly collapsed. As these animals were enveloped in a thin fleshy covering, their calcareous remains may be regarded as portions of the skeleton. Some beds of mountain limestone, in Derbyshire, are almost entirely composed of broken stems and branches of encrinites, not uncommonly called entrochites.

One object of inquiry connected with the study of marine zoology (whether recent or fossil) relates to the depth at which animals can exist below the surface of the sea. When we examine a calcareous mountain, several thousand feet in height, and observe marine organic remains, both in the upper and the lower beds, we might infer, that the animals in the lower beds had originally existed at a depth equal, at least, to the height of the mountain: but this inference would not be a certain one, for the ground may have subsided after the deposition of the lower bed, and other beds may have been subsequently formed upon it prior to the final emergence of the mountain from the ocean.

The average depth of the sea is estimated to be from two to five miles: at the lesser of these depths, the total absence of light, and the pressure of the ocean, are conditions supposed to be incompatible with the existence of animal life. If this be really the fact, by far the largest portion of the surface of the globe would be a dead and dark expanse of the watery abyss. We are however under no necessity of admitting this conclusion. An indefinitely smaller portion of light than can be perceptible by the human eye, may suffice for animals very differently constituted

from those which live in the atmosphere. The luminosity of the ocean, and the phosphorescence of decomposing animal or vegetable substance, may afford light, equal to all the wants of the lowest tenants of the deep. With respect to the pressure of the ocean, it is so great, at depths much less than what certain animals do subsist at, that their means of resisting the effect of such pressure are perfectly mysterious, and therefore we cannot limit the extent to which this pressure may be increased without the destruction of life. Captain Scoresby states, that the surface of a whale which may amount to 1540 square feet, supports under the atmosphere, a pressure of 1386 tons, but at the depth of 800 fathoms in the sea, the pressure is increased to 211,000 tons, equal to the weight of six of the largest ships of the British navy, when fully manned, and provisioned for a six months' voyage. A hollow ball of metal, when sunk a few hundred yards in the sea, is crushed flat: how then can the chambered shell of the nautilus resist such a pressure, except by admitting water within the cells. A cockle shell, if it closed so tight as not to admit water, would at great depths be crushed by external pressure, but the pressure from without would be instantly removed by opening the shell.

I am inclined to believe, that some communication exists between the siphunculus and the chambers of chambered shells, by which water is admitted internally, to resist the external pressure. It is true Mr. Owen could discover no communication between the siphuncle and the chambers in the shell of the nautilus, but it must be remembered, that the specimen he examined had been dead several months, and was preserved in spirits.

The more important difficulty, however, remains unexplained, *how animal life can be preserved from the effects of great pressure?* Wood, when submerged in the sea to the depth of about 1500 yards, had the pores so filled in a short time, that it was much heavier than water, and sunk like stone. The mysterious principle of life and sensation, which the sacred historian impressively calls "the breath of the Creator," can, we well know, suspend the laws of chemical affinity, or preserve living bodies from their influence, but when life is withdrawn, these affinities commence their operation, and decomposition takes place. Perhaps the living principle has in some cases the power also of suspending the effects of terrestrial gravitation or pressure. How this resistance to chemical affinity and to gravitation is effected, is probably placed beyond the reach of human discovery.

INTRODUCTION TO GEOLOGY.

CHAPTER I.

Objects of the Science denominated Geology.—Definitions of Geology and Physical Geography.—The Shape and Density of the Earth.—Opinions respecting the internal Parts of the Globe.—Central Heat.—Temperature of the Earth.—Sea and dry Land.—Proportion of the Earth's Surface habitable by Man.—On the Appearances which led to the first Division of Rocks into Primary and Secondary.—Classification of Rocks.—Districts in which the different Classes appear in England.—The present Islands and Continents formerly covered by the Ocean.—Existing Proofs of this in Great Britain and various Parts of the World.—Fossil Remains of Marine Animals, Vegetables, and land Quadrupeds; the Strata in which they are imbedded formed in Succession at different Epochs.—On human Bones occasionally imbedded in Rock.—Inferences respecting the former Condition of the Globe.—Remarkable Passage in the Institutes of Menu.

In this Chapter the author has endeavored to give such an outline of the science, and its practical application to the knowledge of the Geology of England, as may be clearly and easily understood by the general reader, and prepare him for the perusal of the succeeding Chapters.

There are perhaps few persons possessed of much curiosity in early life, to whom the following question has not frequently presented itself—*What is the world made of?* Now this question, with certain conditions, comprises the most important objects of geological research; namely, *What are the substances of which the Earth is composed? What is the order in which they are arranged? What are the changes they appear to have undergone?* But how are satisfactory answers to these inquiries to be obtained?

When we examine the terrestrial globe, where the solid parts are uncovered and exposed to our view, we observe vast masses of rock or stone lying in apparent confusion on each other; or, should we perceive some regularity in their position and arrangement, we soon lose sight of it again by the intervention of other rocks. In this department of nature all seems vast, unshapen and chaotic; but let us not be discouraged, for we may recollect that the grandest objects in the material universe, seldom present to the hasty view of the superficial observer, immediate proofs of order or design.

The shepherd who first discovered that the planets were not fixed in the heavens, and noticed their apparently intricate wan-

derings among the stars, could not possibly anticipate the regularity and harmonious simplicity of their movements, which subsequent observations have demonstrated.

Let us then endeavor to ascertain by what means we may become acquainted with the structure of the solid covering of our globe. Were these means bounded by the power of man to penetrate below the surface, our knowledge must ever remain very limited and imperfect; but natural operations have greatly facilitated our inquiries, and have broken the rocky pavement of the globe, and raised up or laid bare the mineral substances of which it is composed. By an attentive examination of the situations where the rocks and strata are thus exposed to our research, we lay the foundation of the science denominated Geology.

Geology is derived from two Greek words, *ge* "the earth," and *logos* "reason or discourse," and signifies the Science of the Earth. Werner and his disciples, and also some of the French geologists, have changed the term into *Geognosy;* but for this change no sufficient reason can be assigned, and it is contrary to established analogies of language.

Philosophers, in former ages, neglected the examination of the earth, and contented themselves with vain speculations respecting its formation; whereas the only proper answer to the question, *How was the world made?* is briefly this—"By the almighty power of its Creator." We may however be permitted, and indeed we are almost irresistibly impelled, to inquire into the nature of the secondary causes, that have been operative in reducing the surface of our globe to its present state. This inquiry comprises what may properly be denominated Speculative Geology. Nor is this, as some assert, entirely useless: the advocates of particular systems have engaged in an active examination of nature to support their opinions, and have "compassed sea and land to gain proselytes:" thus numerous facts have been discovered, with which we should not have been acquainted had they remained idle in their studies.

Geology is sometimes considered as a branch of Physical Geography; indeed, an outline of the physical geography of a country or continent must precede any intelligible account of its geology. Physical Geography comprises the extent, form, elevation, and inequalities of the surface; the direction of the mountain ranges and rivers; and the seas, lakes, or natural boundaries by which the country is surrounded.

The geologist, then, directs his attention to the three peculiar objects of his research. These have been already briefly stated, page 1; but it may be useful here to explain them more fully.

1st. *The materials of which the solid crust of the globe is composed.*—To discover these, we must examine the mineral composition and character of the principal rocks and strata, and

observe what peculiar minerals, metallic ores, or organic fossil remains they may contain.

2d. *The arrangement of rocks and strata.*—We must endeavor to ascertain the relative position and the order in which different beds succeed or cover each other, and carefully notice what fractures or dislocations have broken or displaced the beds, subsequently to their deposition; also the volcanic phenomena, if any; and the scattered fragments of rock and beds of sand or gravel that are found upon the surface.

These inquiries relate to the present state of the globe, from which alone we can form any rational inductions respecting its former condition.

3d. *The changes which the surface of the Earth has undergone.*—This branch of the science is supplementary to the other two; but by some it is regarded as forming the principal object of geology.* Some of the changes, as from submersion under the ocean, to elevation above its surface, are satisfactorily proved; others are involved in more or less obscurity. With respect to the causes by which these changes have been effected, the inquiry falls properly within the domain of speculative geology; and, however attractive such investigations may be, they should be considered rather as forming the poetry of geology, than the science itself; the causes which have produced these changes being generally placed beyond the reach of human observation. When a mass of rock is upheaved and overthrown, or a city suddenly engulphed, we ascribe the cause of the displacement or removal to an earthquake; but the earthquake itself is only the effect of a cause which remains to be discovered.

The earth is now well known to be one of those globular bodies called planets, that revolve round the sun in orbits nearly circular, and in stated periods of time, which bear a certain ratio to their respective distances from it. They turn round their axes with different degrees of velocity; and this motion appears to have had considerable influence on their external shape, by enlarging their equatorial diameters: they are not perfect spheres, but are more or less flattened at their poles.

In the planet Jupiter, the velocity of the equatorial parts is more than four hundred miles per minute; whilst in the same time the equatorial parts of the earth have moved only seventeen miles. A difference between the polar and equatorial diameter of Jupiter is perceptible with a telescope that has a distinct magni-

---

* The definition of Geology given by Mr. Lyell, appears to limit the science to the investigation of past changes: "*Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it inquires into the causes of these changes, and the influence they have exerted in modifying the surface and external structure of our planet.*"—Principles of Geology, Chap. I.

fying power of a hundred times, and it is ascertained to be as 12 to 13. The equatorial diameter of the earth exceeds its polar about twenty seven miles; the length of the equatorial diameter being seven thousand nine hundred and twenty seven miles, that of the polar seven thousand nine hundred miles.

The relative density of the sun, the earth, and of the other planets, is estimated by the attractive force which they exert on each other, as they move round their common centre of gravity. The absolute density, or the quantity of matter contained in the earth, compared with an equal bulk of any known substance, may be nearly determined by the attractive force which any given mass of matter exerts upon a plummet (when suspended in its vicinity) to draw it from a vertical line.* This will be proportional to the absolute quantity of matter in that mass compared with that of the earth. By this method it has been found, that the mean density of the earth is about five times greater than that of water, or nearly twice the average density of the rocks and stones on the surface; hence it has been inferred that the interior part of the earth is solid; or, if it be cavernous, that the solid matter must possess great density. It is not improbable that iron, nearly in a metallic state, may be one of the constituent parts of the central mass, and to this it may owe its magnetic polarity.

Dr. Halley supposed that the earth is a hollow sphere, containing within it a central magnetic globe, and that the revolutions of this globe on its axis occasioned the variations of the magnetic needle. Laplace, the celebrated French astronomer, asserts, that the nutation of the earth's axis, and experiments on the vibration of the pendulum, indicate an increase of density of the mineral beds, as they approach nearer to its centre, at least to a certain depth from the surface. The rapid transition of motion to very distant parts of the earth during violent earthquakes, renders it probable that there are cavities filled with fluid or gaseous matter, which extend to different parts of the globe, at great depths under the surface.

An opinion has long been entertained, that our planet contains within it a mass of igneous matter, the source of central heat, which is supposed to be an important agent in maintaining the present temperature of the globe; nor are facts wanting to lend support to this opinion. The occurrence of numerous active volcanoes in both hemispheres, and in every degree of latitude; the existence of extinct ancient volcanoes, and of rocks of igneous origin in almost every country; and the numerous hot and warm springs that preserve an unvarying temperature for centuries,—all

* A series of experiments are now in progress by the Astronomer Royal, Dr. Airy, to ascertain with greater accuracy the density of the earth.

indicate the existence of a source of heat deeply seated beneath the surface. It seems also to be proved by observations made for the purpose in deep mines, that the temperature of the earth increases as we descend; though at a small distance from the surface, the temperature of the ground and of wells is the same in every season, but it varies in different latitudes. The animals and vegetables, whose remains in a fossil state are found in northern climates, are, for the most part, analogous in structure to the animals and vegetables of tropical climates; hence it has been inferred by some geologists, that the central mass of heat is gradually refrigerating. It is, however, the crust of the globe that offers proper occupation to the geologist. The greatest depth to which he can extend his observations from the uppermost strata, to the very lowest beds that have been raised up or laid bare by these natural operations which have formed mountains or valleys, is less than eight miles; a thickness which, compared with the bulk of the earth itself, does not exceed that of a coat of varnish upon an artificial terrestrial globe. Were we to bear this sufficiently in mind, the mighty catastrophes which have changed the surface of the globe in former periods, and have left traces of their action, appalling to the imagination, would cease to exceed the sober measure of belief.

The superficies of our planet is calculated to contain about one hundred and ninety millions of square miles; but could we be raised to a sufficient height above the earth, so as to have its whole enlightened hemisphere for our horizon, we might perceive, as it revolved under our feet, how small a portion is fitted for the habitation of man. More than three fifths of the earth's surface are covered by the ocean; and if from the remaining part we deduct the space occupied by polar ice and eternal snow, by sandy deserts, sterile mountains, marshes, rivers, and lakes, the habitable portion will scarcely exceed one fifth of the whole of the globe. Nor have we reason to believe, that at any former period the dominion of man over the earth was more extensive than at present. The remaining four fifths of our globe, though untenanted by mankind, are for the most part abundantly stocked with animated beings, that exult in the pleasure of existence, independent of human control, and no way subservient to the necessities or caprices of man. Such is and has been for several thousand years the actual condition of our planet; nor is the consideration foreign to our subject, for hence we may feel less reluctance in admitting the prolonged ages or days of creation, when numerous tribes of the lower orders of aquatic animals lived and flourished, and left their remains imbedded in the strata that compose the outer crust of our planet.

The ocean has been an important agent in effecting vast changes on the surface of our globe, which will be afterwards

considered. The average depth of the sea has been differently estimated. According to Laplace, this depth cannot be less than ten miles, to account for the height of the tides by the laws of gravitation; but it is more generally admitted, that the average depth does not exceed five miles. No admeasurement by soundings has exceeded the depth of one mile and a quarter.

The ocean has not always occupied its present bed, for rocks, entirely composed of the shells or remains of marine animals, are found in almost every country that has yet been explored; and these remains occur near the summits of the highest mountains, in the old and new continents, some of which rise more than two miles above the present level of the sea.

It is well known that the water of the sea contains a considerable portion of common salt, and a small portion of other saline ingredients.* The average amount of salt in the ocean may be estimated at two and a half per cent. of common salt, and one half per cent. of other saline compounds.

The atmosphere which surrounds the earth does not come under the attention of the geologist, except as an agent in wearing down the solid surface, by the precipitation of rain, and by change of temperature. The inequalities of the earth's surface formed by mountains and valleys, afford frequent opportunities for observing, that the mineral substances of which it is composed are of different kinds: in some situations, we observe strata of chalk; in others, of sandstone, or compact limestone, or beds of slate, granite, &c. It was long known to working miners, that the different beds of mineral matter lay over each other in a regular order in certain districts, and that certain beds were always found under, and never above, other particular beds.

The first observations which may be said to have laid the foundation for a correct classification of rocks, were made by the German, Lehman, about the middle of the last century. He found that the lower rocks, in some of the mining districts, were distinguished from the upper rocks by their great hardness, and by their structure, which was, for the most part, either crystalline or slaty; they were also distinguished by the absence of shells and other organic remains, and by the absence of fragments of other rocks, which occur so frequently in the upper rocks or strata. He further observed, that many of the upper strata, be-

* The inquiry has often been made,—Whence did the sea derive its saline contents? It has been supposed by some writers, that the salt in the sea has been gradually augmented by saline particles brought into it by rivers; but this cause is totally inadequate to explain the immense quantity of salt existing in the whole mass of the ocean. If the average depth of the sea be five miles, and it contain two and a half per cent. of salt,—were the water entirely evaporated, the saline residue would form a stratum of salt more than five hundred feet in thickness, covering three fifths of the surface of the globe.

sides containing organic remains, appeared to have been formed of fragments of the lower rocks, broken down and agglutinated together; and hence he inferred, that the lower rocks were formed prior to the creation of animals, and he gave them the name of *Primitive* or *Primary*, and distinguished the upper by the name of *Secondary*. This grand division, though too hastily formed, was of use in the infancy of the science, and induced naturalists to examine more attentively the nature and position of the rocks in different countries: and, as their observations became more extended and accurate, a more extended arrangement and classification was found necessary. Many of the earlier geologists maintained, that each bed or stratum of rock is spread universally over the globe, and that a series of beds, in regular succession, environs our planet, like the coats of an onion. This position is, however, much too general, as many beds of rock which are common in one country, are entirely wanting in another; but, taken as an illustration of the structure of the crust of our globe over a certain extent, the successive coats of an onion, if they were of different colors, might not unaptly represent the different strata that cover certain districts.

It may here also be proper to observe, that the different strata which occur under each other, are not arranged in the order of their density or specific gravity. Coal strata, for instance, are often covered with strata of ironstone, the specific gravity of which is more than twice that of coal.

I shall now proceed to enumerate the different classes of rocks generally admitted by geologists, and briefly describe the principal characters of each class; and, in order to direct the attention of the reader more forcibly to the subject, I shall trace on an outline map the principal situations in our own island, where rocks of each class occur, except the recent volcanic.

All the different rocks and strata that cover the earth's surface may be arranged under the following classes:

1. Primary.
2. Intermediate, or Transition.
3. Secondary.*
4. Tertiary.
5. Basaltic and Volcanic.
6. Diluvial and Alluvial ground.

This arrangement is substantially followed by most geologists of the present day, though with some modification of the names. Several of the French geologists class the lower secondary, including the coal strata, with the intermediate or transition rocks: some urgent reasons may be advanced for this, which we shall

* By some geologists, these secondary strata are called "the older" and "the younger series," terms which are equally clear and intelligible.

subsequently notice. Objections have been made to the terms primary, secondary, &c., that they do not strictly conform to the present state of geology; but a change of names, which are in general use and well understood, would be attended with no adequate advantage, and would be ill suited to promote the knowledge of the science in an introductory work. It is greatly to be regretted, that a morbid desire to obtain celebrity by inventing new nomenclatures, should so much prevail among some of the cultivators of natural science. The author is of opinion, that a more simple arrangement of rocks might be made without any material change of the present names, and he is persuaded that such an arrangement will take place in a more advanced state of the science. (See Chap. V.)

Primary or *Primitive Rocks*—were so called because no fossil remains of animals or vegetables, nor any fragments of other rocks, were found imbedded in them: hence it was supposed that they were formed prior to the creation of organic beings. The rocks of this class are for the most part extremely hard, and the minerals of which they are composed, are frequently more or less perfectly crystallized. These rocks generally occur in immense masses or beds; they form the lowest part of the earth's surface with which we are acquainted, and they not only constitute the foundation on which rocks of the other classes are laid, but in many situations, they pierce through the incumbent rocks and strata, and form also the highest mountains in Alpine districts. We are not to conclude, when we see a mountain or range of mountains bounded by a plain, that the mineral beds and strata of which these mountains are formed, terminate at their apparent basis; on the contrary, they dip under the surface at angles more or less inclined, stretching below the lower grounds and hills, and often rising again in remote districts.

That primary rocks environ the whole globe, will not admit of direct proof; but from their frequent occurrence in mountainous districts in the most distant parts of the world that have been examined, we may infer that some of the rocks of this class constitute the foundation rock of every country. We have no means of ascertaining that the similar rocks of distant districts were formed at the same time, nor can we be certain that the rocks called Primary, have not once contained organic remains, that were destroyed during the process by which they acquired their present crystalline structure. We may, however, with apparent probability, infer that their formation was prior to the existence of animals or vegetables on our planet in its present state, because the rocks which immediately cover them, contain almost exclusively, the organic remains of the lowest class of animals, which are considered as forming the first link in the chain of animated beings. On this account these rocks have been called by the

German geologists, *transition* rocks, from the supposition that they were formed when the world was passing from an uninhabitable to a habitable state.

Transition or *intermediate rocks* are generally less crystalline than the primary; they contain occasionally organic remains of the lower classes of animals, and also fragments of rocks of the primary class. The lower series of these rocks are frequently interposed between rocks of the primary class, and those generally called secondary, and often partake of the character belonging to both. The prevailing rocks in the transition series are limestone, slate, called clay-slate, and coarse slate, passing sometimes into sandstone, and conglomerate; this has been called by the Germans *grau wacçé*, or greywacke. The rocks of the primary class and the lower transition rocks are the principal repositories of metallic ores; but in Europe they contain few saline or inflammable minerals.* In South America, according to Humboldt, sulphur and bitumen exist in considerable quantities in rocks denominated primary.

The regular coal strata, sometimes called the great coal formation, and by Werner "the independent coal formation," occurs in certain districts of limited extent, covering the transition rocks, of which it may be stated to constitute the upper series, as no well characterized line of separation can be traced between them. They constitute a group of strata composed of sandstone, soft slaty beds called shale, and beds of coal and ironstone. Many of these strata abound in fossil remains of plants analogous to ferns, palms, and reeds, and to the present vegetation of tropical climates.

The lower series of the transition beds, below the regular coal strata, contain almost exclusively the remains of marine animals. This difference in the organic remains, indicates an important change in the conditions under which the lower series of transition rocks and the coal strata were deposited. The lower series were for the most part formed under the sea.

Secondary strata.—The prevailing beds in this series are stratified limestone, with beds of clay, shale, and sandstone interposed. The limestone has generally an earthy texture, and very rarely partakes of the hard and crystalline character of the lower limestones. The fossil remains in the upper secondary strata are, with some exceptions, those of marine animals, but of different genera or species from those in the strata below them. It is in the upper secondary strata that we first meet with remains of saurian or lizard-shaped animals, some of which were of immense size. The co-existence of dry land, at the period when most of the secondary strata were deposited, is, however, proved, by the occasional occurrence of terrestrial fossil plants, and the bones of

* Except we comprise the regular coal formation in the transition series.

fresh-water and amphibious reptiles, such as the crocodile and tortoise.

An important inference respecting the secondary strata deserves here to be noticed; they appear to have been deposited long after the lower and upper series of transition beds had been deposited and solidified, and after a series of convulsions had greatly fractured and displaced the beds already formed; for the secondary strata do not lie parallel with the lower transition beds, and coal strata, but generally cover them in what geologists call an unconformable position.

To make this better understood, suppose a number of books to be laid regularly upon each other, and the lowest volume to be tilted up so as to give an inclined position to the whole, if we then take other books and place them horizontally, or nearly so, on the upper edges of the inclined volumes, we may then form a distinct idea of the unconformable position of the series of secondary strata over the lower series. This position is represented Plate 1, fig. 3; it will be more fully described in the 4th chapter.* The last of the upper secondary strata is chalk, a rock well known in the south and southeast parts of England, though entirely wanting in the northwest and in Scotland.

Tertiary Strata comprise all the regular beds that have been deposited subsequently to the chalk strata, on which they frequently repose. It was formerly supposed that tertiary strata were very limited in extent, and were confined to a few districts in Europe; recent observations, however, prove that strata of this class cover considerable portions of the surface in various countries, though there are other countries in which they are entirely wanting. Tertiary strata are the most recent or uppermost of all the regular rock formations. They consist chiefly of clay, marl, limestone, and friable sandstone: the lower series of these strata contain numerous marine shells, while some of the middle and upper strata contain shells resembling those found in our present rivers, or in fresh-water lakes. The most remarkable fact respecting the tertiary strata is, that some of them contain numerous bones of large terrestrial quadrupeds of the class Mammalia; but these for the most part belong to genera or species which no longer exist upon the earth.

Volcanic and Basaltic Rocks have been either ejected from volcanoes, or poured out in a state of fusion from rents and openings on the earth's surface. They cover in an irregular manner the rocks of the preceding classes. In some situations the melted mineral matter has taken a columnar form in cooling; in other

---

* There are some situations in which the lower strata have not been subjected to any great dislocations prior to the deposition of the upper strata upon them, for the latter occur in a position parallel with that of the lower strata.

situations it fills vast fissures, called by the miners *dykes*. Basaltic rocks are very common in the northern part of our island. Volcanic and basaltic rocks are of different ages: the most ancient approach in their nature to rocks of the primary class, and appear to be chiefly formed of the same mineral substances, more or less softened by subterraneous heat, and protruded through the crust of the globe.

Diluvial and Alluvial.—Considerable portions of the surface of the ground are in many countries covered with thick beds of gravel, sand, or clay, and fragments of rock and loose stones, more or less rounded by attrition. In some situations these have evidently been transported from a vast distance, for frequently no rock similar to the fragments occurs within a hundred miles or more of the place where they are deposited. They indicate the action of torrents and inundations, which have swept over the face of our present continents. The French have given to these depositions the name of *terreins de transport*, a name which defines them precisely, and involves no theory; for it comprises both deposits formed suddenly by mighty irruptions of the ocean, and alluvial deposits formed by the gradual deposition of sediment at the mouths of rivers or in lakes.

The classes of rocks above enumerated have their appropriate mineral productions, and, with the exception of rocks of the first and fifth classes, their appropriate organic remains; and it would be as useless to search for regular beds of common coal in the primary rocks, as it would be to search for metallic veins, or statuary marble, in the tertiary strata.

It has been before stated, that we cannot be absolutely certain that rocks of the same class and of a similar kind in distant countries were formed at the same time. This is more especially the case with rocks that contain no organic remains, such as granite, porphyry, and volcanic rocks, as it is only from their relative position that we can obtain evidence respecting their geological antiquity. Those rocks which generally serve as the foundation for the other classes, are inferred to be the most ancient. Strata in the same class, that contain similar species of organic remains, are admitted to belong to the same geological epoch, and to have been deposited under the same condition of the globe; yet, admitting that certain distant strata were of coeval formation, it may be proved, that portions of the same series of strata have emerged from the ocean at different intervals of time, and that certain parts of the present continents have become dry land at very distant and remote epochs. The period when rocks or strata were first deposited has no necessary connection with the period of their elevation, as will be afterwards more fully stated.

I shall proceed to elucidate the situation of the different classes of rocks in England, by a reference to the outline map, Plate 6.

The waving line A A A, extending from the southwest of Dorsetshire to the county of Durham, forms a striking geological division of England: all the land on the east of this line is composed of the upper secondary and tertiary strata, in which neither metallic veins nor regular beds of mineral coal are found. The tertiary strata lie over the upper secondary, within the parts bounded by the letters *o o o o*. On part of the eastern coast of Yorkshire and Lincolnshire, there is a submarine forest about seventeen feet under the present high-water level. This forest appears to have extended eastward, as stumps of trees and roots may be seen at low water at a considerable distance from the coast.

In various parts west of the line A A A there is an important change in the mineral productions; from thence to the line C C C the coal strata appear, and most of the principal coal districts in England occur betweeen the lines A A A and C C C. It is remarkable, that few, if any, regular metallic veins are found in this division. The coal strata and the lower secondary strata are also continued west of the line C C C, through the midland and northern counties, but rocks of the lower transition series, occasionally appear in this part of our island. A very extensive coal district occurs in that part of South Wales bordering the Bristol Channel. On the east of the line C C C it may be remarked, that the strata generally incline or dip to the southeast; west of this line they are more irregular, and dip in various directions.

West of the part composed of the lower secondary and coal strata, colored green, we meet with rocks of the primary and transition classes, in which metallic ores are found; they constitute the alpine parts of England, passing through Cornwall and Devonshire, into North Wales, and the northwest parts of Yorkshire and Lancashire, and through Westmoreland and Cumberland into Scotland. This part is colored red; rocks of the primary class chiefly occur in the parts distinguished by dark lines.

Near the centre of England, at Charnwood Forest in Leicestershire, and at the Malvern Hills in Worcestershire and Herefordshire, the primary rocks pierce through the secondary strata, and compose two small districts of primitive country surrounded by secondary strata. Also in the counties of Derbyshire and in the West Riding of Yorkshire, and part of Cumberland and Westmoreland, rocks of transition or mountain limestone rise to a considerable elevation from beneath the coal strata which occur east and west of them; some of these limestone mountains are rich in metallic ores. Along the line E E beds of rock-salt and the principal springs of brine are situated.

It must be kept in mind when observing this map, that the tertiary strata lie upon the secondary, and the secondary upon the transition and primary rocks. Now, if the tertiary and second-

ary strata had both extended to the western counties, it is obvious that we could have had no knowledge of the existence of the lower series, but by boring or sinking through the upper series; and the aggregate thickness of these exceeds the power of the miner to pierce through. The tertiary strata, however, only cover a part of the secondary, and the secondary do not cover the whole of the lower series; so that in travelling westward, we come immediately upon the lower strata in succession, as they rise from underneath each other; for, as I before observed, the general inclination or dip of the beds is towards the southeast. The action of the sea upon our coasts and cliffs, has exposed to view the succession of the different rocks and strata in many parts of our island, and has enabled us to obtain a correct knowledge of their thickness and direction, and of the organic remains peculiar to each series.

Before concluding the present chapter, let us take a view of some of the more striking appearances, which afford demonstrative evidence, that great changes have taken place in the relative level of the present continents, and that the ocean has, in former ages, rolled its waves over what are now the most elevated parts of the earth. Many proofs of this exist in our own island, and in various parts of the world.

The calcareous or limestone mountains in Derbyshire, and Craven in Yorkshire, rise to the height of about two thousand feet above the present level of the sea. They contain through their whole extent, fossil remains of zoophytes and marine animals, but more abundantly in some parts than in others. Particular species occupy almost exclusively distinct beds, and in some situations the whole mass appears a compact congeries of mineralized organic remains. Over these vast beds of ancient limestone occur a series of sandstone strata and shale, containing almost exclusively remains of terrestrial vegetables associated with beds of coal. Above this series we meet with other calcareous strata, containing remains of fish and enormous reptiles of the saurian or lizard tribe, intermixed with numerous species of bivalve and univalve shells, but of different genera or species from those living in the present seas. Again, in the uppermost or tertiary strata, we meet with bones and teeth of land quadrupeds of the class Mammalia, some of which belong to unknown genera, and nearly all to unknown species. Among these are the bones of large animals, as the mastodon, the elephant, the rhinoceros, the hippopotamus, and the gigantic tapir. These large animal remains occur chiefly in beds of clay or gravel, or in caves. In the latter situation they are abundantly mixed with bones of smaller quadrupeds, of which the species no longer exist in England.

The calcareous mountains of the Jura, and the outer range of the Alps, contain beds filled with the remains of marine animals,

many of which I have examined, and found to be similar to those in the secondary strata in England. In the Alps they occur at the height of from six to eight thousand feet. Similar phenomena are observed in the calcareous mountains of the Pyrenees; and, according to Humboldt, organic remains occur in the Andes, at the height of fourteen thousand feet. The distinct characters of the animals found in the upper and lower beds in these mountains, as well as in those of our own country, prove that they were not brought into their present situation by any sudden inundations, which would have mixed different orders of animals together. The beds which contain exclusively the remains of animals of the same species, must have remained for ages under the ocean; for these animal remains often compose nearly the whole substance of a bed of limestone of great thickness, as is the case with the beds of encrinal limestone in Derbyshire, and the limestone called coral-ragg at Steeple Ashton.

The fossil remains of species of animals not now in existence, entombed and preserved in solid rocks, present us with durable monuments of the great revolutions which our planet has undergone in former ages. We are carried back to a period when the waters of the ocean have covered the summits of our highest mountains, and are irresistibly compelled to admit one of two conclusions,—either that the sea has retired and sunk far below its former level, or that some power operating from beneath, has lifted up the islands and continents, with their hills and mountains, from the watery abyss, to their present elevation above its surface.

These organic remains present also undeniable proofs of another fact equally interesting. Every regular stratum in which they are disseminated was once the uppermost rock, however deep it may be below the present surface, or with whatever rocks it may now be covered. This inference is not the less conclusive, whether we suppose that the animals lived and died where their remains occur, or whether they were aggregated and carried by marine currents into their present situation. Hence we learn that the secondary strata were formed in succession over each other, and thus these fossil remains preserve the records of the ancient condition of our planet, and the natural history of its earliest inhabitants. The unknown causes by which zoophytes and different genera and species of testaceous animals, of reptiles, vegetables, and mammiferous quadrupeds were buried in different strata, have operated in succession at different intervals of time; for we do not find the remains of different classes confusedly intermixed together, except in beds of clay or gravel, near the surface, or in fragments of various rocks which have been broken down and subsequently united. Bones of vertebrated animals, or such as had a brain and spinal marrow, have never been found in the

lower strata, except those of a few species of fish; nor have the bones of large mammiferous quadrupeds ever been discovered below the chalk. Hence we acquire a perfect certainty, that the different beds which form the crust of our planet were deposited in distant epochs, and under different conditions of the globe. The animal remains in some of the strata are so delicate, and so regularly deposited, that we can have but little doubt that the animals lived and died tranquilly where their remains are now found: in other strata the remains are dispersed and broken, and the animals appear to have perished by some sudden convulsion.

If the bones of man, or of large mammiferous quadrupeds resembling existing species, have casually been found with fossil remains peculiar to the lower or more ancient strata, I believe a careful examination of all the circumstances, would generally explain the apparent anomaly. I shall state a remarkable fact of this kind, which came to my knowledge when engaged in a mineralogical examination for the Earl of Moira, in the vicinity of Ashby-de-la-Zouch, in Leicestershire: it will evince how cautious we ought to be in drawing general conclusions in geology, from single facts. A thick bed of coal belonging to his lordship, at a place called Ashby Wolds, is worked at the depth of two hundred and twenty five yards; it is covered with various strata of ironstone, coal, and solid sandstone. On an estate adjoining to his lordship's manor, in the same bed of coal (which is ninety seven yards below the surface,) the entire skeleton of a man was found imbedded. No appearance existed of any former sinking for coal; but the proprietor ordered passages to be cut in different directions, until the indication of a former pit was discovered, though the coal had not been worked. Into this pit the body must have fallen, and been pressed and consolidated in the loose coal by an incumbent column of water, previously to the falling in of the sides of the pit.

The imperfect skeleton of a woman, imbedded in a kind of calcareous sandstone, brought from Guadaloupe, and exhibited in the British Museum, may appear to invalidate what was asserted in the first edition of this work, that no instances have been known of human bones being found in regular stratified rocks, nor even in undisturbed alluvial ground, where the remains of extinct species of quadrupeds are not unfrequently met with.* Due attention to all the circumstances, will reconcile that asser-

* Since the publication of the first and second editions of this work, I have seen in the possession of a gentleman at Plymouth, one of two human skulls that were found in digging a stream-work, forty or fifty feet below the level of the river at Carnon in Cornwall. Nuts, and the horns of some animal allied to the stag, were discovered in the same situation.—In a note I made at the time, 1816, it is stated that the forehead was remarkably low and narrow, and the part of the skull which contained the cerebellum unusually prominent. That these skulls were ancient

tion with the present fact. The skeleton from Guadaloupe is described as having been found on the shore below the high water mark, among calcareous rocks formed of madrepores, and not far from the volcano called the Souffrière. The bones are not petrified, but preserve the usual constituents of fresh bone, and were rather soft when first exposed to the air. Specimens of the stone which I have in my possession, that were chipped from the same block, present, when examined with a lens, the appearance of smooth grains, consisting of rounded fragments of shells and coral, aggregated and united without any visible cement.

We have an example of a similar formation of calcareous sandstone on the north coast of Cornwall, composed entirely of minute fragments of shells. In the Arundel papers, there is mention of an inundation of sand, which covered a great part of the coast near St. Ives in the twelfth century: it is also known by oral tradition, that whole farms have been overwhelmed at a period not very remote; and at this very day, upon the shifting of the sands by high winds, the tops of houses may occasionally be seen. In several parts of the coast, this sand is seen passing into the state of compact rock, very difficult to break; and it is even used for building stone. Entire shells of land snails and fragments of slate occasionally occur in it.* When I was in the county I examined numerous specimens of the rock with a lens, and compared them with a specimen of the Guadaloupe sandstone that I had with me, and they appeared closely to resemble each other. Dr. Paris, in an interesting paper read to the Geological Society of Cornwall, ascribes the consolidation of the sandstone to the infiltration of water containing iron, from the decomposing slate rocks in the vicinity. Instances of the consolidation of beds of loose sand are common on the coast of Sicily. It cannot therefore excite surprise, that in a volcanic island like Guadaloupe, subject to violent convulsions from earthquakes, inundations, and impetuous hurricanes, human bodies should occasionally be discovered, that have been enveloped in driving sands, which have subsequently become indurated. The situation of this skeleton near the sea shore, the state of the bones, and the nature of the stone in which they are imbedded, take away the probability of their high antiquity.

In the Institutes of Menu, which according to Sir William Jones are nearly as ancient as the writings of Moses, the account

---

there can be little doubt, but there are no sufficient data to enable us to approximate to the period of their deposition.

The bone was not mineralized, though very hard. The absence or extreme rarity of human bones in these beds of gravel and clay, or in caves that contain the remains of large land quadrupeds, is far more extraordinary than their non-occurrence in the regular strata that cover our present continents.

* See Guide to Mount's Bay and the Land's End.

of the six days of creation so closely resembles that given in Genesis,* that it is scarcely possible to doubt its being derived from the same patriarchal communication. There is, however, a particular definition given of the word *day* as applied to the creation, and it is expressly stated to be a period of several thousand years. If this interpretation be admitted, it will remove the difficulty that some have felt in reconciling the epochs of creation with the six days mentioned by Moses. The six days in which Creative Energy renovated the globe and called into existence different classes of animals, will imply six successive epochs of indefinite duration. The absence of human bones in stratified rocks or in undisturbed beds of gravel or clay, indicate that man, the most perfect of terrestrial beings, was not created till after those great revolutions which buried many different orders and entire genera of animals deep under the present surface of the earth. That man is the latest tenant of the globe, is confirmed by the oldest records or traditions that exist of the origin of the human race.

The great convulsions which have at distant periods changed the ancient surface of the globe, and reduced it from a chaotic to its present habitable state, were not, it is reasonable to believe, effected by the blind fury of tumultuous and conflicting elements, but were the result of determined laws, directed by the same wisdom which regulates every part of the external universe. Compared with the ephemeral existence of man on the earth, the epochs of these changes may appear of almost inconceivable duration; but we are expressly told, "that with the Creator a thousand years are as one day, and one day as a thousand years."

* The discoveries in astronomy, which proved the diurnal and annual motions of the earth, were for some time warmly opposed, as being at variance with the motion of the sun and moon, and the motionless stability of the earth which the sacred writings describe. We should not, however, admire the judgment of the writer, who in the present day should publish a *scriptural astronomy*, in opposition to the Copernican system. The sacred writers describe natural objects as they appear to the senses, and do not teach systems of philosophy.

CHAPTER II.

ON FOSSIL, ANIMAL, AND VEGETABLE REMAINS, OR PALEONTOLOGY.*

Opinions of early Naturalists respecting Petrifactions.—On the Process called Petrifaction.—Experiment of Dr. Jenner on the Petrifaction of recent Bones.—Living Reptiles occasionally found in solid Stone.—Remarkable Difference in the Condition of Fossil Remains in adjacent Strata; Instance of this at Westbury Cliff, Gloucestershire.—The four grand Divisions of the Animal Kingdom.—Distribution of the Remains of certain Classes and Orders of Animals in each Division through the different Rock Formations.—Fossil Elephant proved to have been an Inhabitant of cold climates.—On Vegetable Petrifactions in the Transition, Secondary, and Tertiary Strata.—On the Progression from lower to higher Forms of Organic Structure.

Paleontology, a term lately introduced, comprises fossil Zoology and fossil Botany, a knowledge of which may appear to the student to have little immediate connection with Geology; the author has therefore at the end of the present Chapter given a summary of the proofs which organic remains afford of the former condition of the crust of the globe.

If it had been predicted a century ago, that a volume would be discovered, containing the natural history of the earliest inhabitants of the globe, who flourished and perished before the creation of man, with distinct impressions of the forms of genera of animals no longer existing on the earth,—what curiosity would have been excited to see this wonderful volume! how anxiously would philosophers have waited for the discovery! But this volume is now discovered; it is the volume of Nature, rich with the spoils of primeval ages, unfolded to the view of the attentive observer, in the strata that compose the crust of the globe. The numerous and varied forms of organic beings, whose remains are there distinctly preserved, sometimes differ so much in structure from any known genera of animals, that we can scarcely hazard any probable conjectures respecting their modes of existence. Nor is it merely the forms of unknown animals that we discover in the different strata; we also learn the order of succession in which they first appeared on the globe.

---

* Paleontology, from the Greek *Palaios* ancient, and *ontology* the science of beings.

It is only within a comparatively short period, that these fossil organic remains have engaged the attention of naturalists. It is true, that in remote times, the occasional discovery of shells and bones of large animals imbedded in rocks, did not escape the attention of philosophers; but, the shells were supposed to belong to species now living, and the bones to a gigantic race of men, that perished during some great inundation, or had been buried by earthquakes. Other hypotheses, equally remote from truth, serve to show how little attention had been bestowed on this department of Natural History. The celebrated botanist, Tournefort, from the regularity of form in many fossil remains, was induced to believe that they were stones that grew and vegetated from seeds. "How could the *Cornu Ammonis*," he observes, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small, as in the larger forms? Who moulded it so artfully, and where are the moulds?"

As fossil organic remains, particularly shells and zoophytes, are found many hundred, and even thousand, feet below the present surface of the earth, the first inquiry that naturally suggests itself is, how did they come there? It is impossible that the animals when living, or their exuviæ when dead, could pass through such vast depths of solid rock. A few of them might fall into vertical fissures, and remain there,* but they could never in this way enter into strata almost entirely composed of organic remains. Besides, the strata now deep under the dry ground are chiefly

---

* Instances of reptiles found living in the midst of solid stone sometimes occur. At the colliery on Rothwell Haigh, near Leeds, a living lizard or newt was found in a bed of coal at the depth of one hundred and eighty yards from the surface. I saw it in the year 1819, soon after its discovery; it was preserved in spirits, and was about five inches in length. I could not perceive that it differed from the living species. The animal had probably crept into the mine along one of the levels that drain off the water, or down the sides of the shaft. The specimen is now in the possession of the Rev. A. Sharp, Vicar of Wakefield. In all instances where toads have been found in solid stone, it is reasonable to believe that they entered through fissures that have been subsequently closed. That these animals will live without food for a great number of years, is proved by the following circumstance:

The late Sir Thomas Blacket, of Britton Hall in Yorkshire, had one cellar which was only opened once a year, as it contained some particularly choice wine which was never brought to table but on the annual celebration of his birthday, which was on the 21st of December, or St. Thomas's day. The butler, when taking out the wine, observed a small toad crawling along the stone floor. He placed the toad under a wine bottle, and thought no more of it till he went into the cellar the following year, when, on removing the bottle, he was much surprised to see the toad immediately crawl. This circumstance he mentioned to Sir Thomas, who descended with his visiters into the cellar to look at the toad, after which, the bottle was replaced, and the poor animal was kept a close prisoner till the succeeding year, when he was again uncovered, and found alive as before. The same annual experiment was continued for more than twenty five years, when the wine was exhausted, the cellar cleared, and the toad, who was still living, was thrown out of doors. Having heard of this circumstance from a person who had lived in the family part of the time, I questioned the old butler respecting it, and he fully confirmed the truth of the story.

filled with the remains of marine animals; nor do we generally find these animal remains confusedly aggregated; different genera or species occupy particular strata, or are associated with certain genera or species of the same class, and never with others. It is therefore evident, that they were not brought into their present situations by vast inundations and buried under the earthy matter which a subsequent inundation cast over them. Neither could zoophytes, fish, or large reptiles, or the inhabitants of bivalve or univalve shells, have lived and flourished in the midst of solid stone. We are therefore led to the conclusion, that each stratum which contains these organic remains was once the uppermost covering of the globe, and that the animals, for the most part, lived and died near where their bones or shells are now found, and were covered by successive depositions of strata, on which following races of living beings flourished, and in like manner left their remains.

Animal or vegetable substances found imbedded in rocks, are more or less impregnated with mineral matter, and hence have been called petrifactions. The process of petrifaction consists in the infiltration of mineral matter into the pores of bone or vegetables. In some instances, the animal or vegetable matter has been almost entirely dissolved or removed, and the mineral matter so gradually substituted, as to assume the perfect form of the internal structure either of the plant or animal.

The process of petrifaction may be more rapidly effected than has generally been supposed. In the year 1817, I paid a visit to the celebrated Dr. Jenner, at Berkley, who informed me that he had made several experiments upon recent bones, by burying them in the dark mud from the lias clay: in less than twelve months the bones became black throughout, and when dry, they were harder, heavier, and more brittle than recent bone, and the surface was shining. The specimens which he showed me, presented the same appearance as the fossil bones in the lias clay. The effect was probably produced so speedily by the presence of the sulphate of iron, and other saline ingredients with which that stratum abounds. As this stratum is the most remarkable of all the secondary series, for the large animal remains which it contains, particularly of the saurian or lizard order, and as the bones are frequently covered with crystals, or incrustations of pyrites, I will venture to hazard a conjecture respecting the manner in which these crystals, or incrustations of pyrites, or sulphuret of iron, are formed. The stratum before mentioned, contains much sulphate of iron or green copperas in solution. I suppose that the carbon in the animal matter had decomposed the sulphuric acid and the oxide of iron, and that the sulphur and iron in their nascent state had united, and formed the sulphuret of iron, or pyrites. I was led to this conclusion by reading an account by

Mr. Pepys, of some mice having by accident been immersed in a jar containing a solution of sulphate of iron: how long they had lain there was unknown; but the remains were partly covered with small crystals of pyrites, which could only have been formed in the manner above suggested. The stone surrounding the organic remains in the lias, I have observed to be considerably harder than the other parts of the same stratum. The organic remains of zoophytes and shells in limestone strata, are also generally harder than the stone in which they are imbedded; and on this account, when the stone has been exposed to the atmosphere a long time, the organic remains rise above the surface.

Organic remains are generally colored by the strata in which they are imbedded; in roe-stone, chalk, and the upper fresh water limestone, they approach to a yellowish or brownish white: in lias, bituminous shale, and dark limestone, they incline to black; and the shells in bituminous shale are sometimes filled with bitumen in a fluid state. In the strata above chalk, the bones and shells retain their original constituent parts very little changed; in chalk, and all the strata under chalk, the organic remains are more or less completely impregnated with mineral matter. The outer crust or shell of many chalk fossils is calcareous, and the internal part filled with flint. In some cases we meet with an internal cast, formed in the cavity of a crustaceous animal, and the external covering has disappeared: in other instances, the shell or crust of the animal has formed a mould in the stone, into which mineral matter has been subsequently infiltered, and has thus made an external cast.

It is particularly deserving attention, that some animal remains contain the most delicate fibres and spines, perfect and unbroken: this proves that the mineral matter in which they are imbedded was deposited in a finely comminuted state, and in a tranquil sea. In some instances, the most delicate shells are regularly arranged in the same position in which the animals lived and died, while the animal remains in the strata above or below them, are broken and confusedly aggregated together. The most remarkable instance of this kind I have ever observed, occurs at Westbury Cliff, on the northern bank of the river Severn, about seven miles below Gloucester. It is a low cliff, nearly perpendicular; the lower part is composed of what is generally called red marl, over which are the lower beds of dark argillaceous limestone and clay, called lias. A few yards above the junction of the lias and red marl, there is a thin stratum of dark micaceous sandstone, entirely filled with bones, and the teeth of the shark, and animals of the saurian or lizard tribe, broken and intermixed in the greatest imaginable disorder. Near the upper part of the cliff, not many feet above the stratum filled with bones, there is a thin stratum of whitish argillaceous limestone, called white lias,

which is filled with the most delicate minute bivalve shells, al-arranged in the same position, without any intermixture with shells of other species.

Facts like these are particularly deserving the attention of the geologist, as they mark in a striking manner the sudden convulsions which the surface of the globe has at different periods undergone.

The stratum, with aggregated bones of saurian animals, appears again on the other side of the Severn, at Aust Passage, where the junction of the lias and red ground may also be observed; but I could not discover there any trace of the white lias bed with the bivalves, similar to those at Westbury Cliff.

Some of the more delicately constructed animals, and the fish whose bodies are found entire, imbedded in stone, appear to have been instantaneously destroyed and enveloped in mineral matter, before the putrefactive process could commence.* The process of petrifaction must also, in some instances, have commenced almost immediately after the death of the animal. In some specimens of fossil fish from chalk, in the museum of Mr. Mantell of Lewes, the stomach is uncompressed, and is filled with mineral matter.

In tracing the different animal remains that occur in the lower, the middle, and the upper strata, the circumstance most worthy of notice is the first appearance of any of the different divisions and classes of animals, and of the orders, genera, or species belonging to each division. In the luminous arrangement of Baron Cuvier, in his *Règne Animal*, all animals are distributed, according to their organization, into four grand divisions—*Vertebrated*, *Molluscous*, *Articulated*, and *Radiated.*

1st, *Vertebrated.*—Animals which have a skull, containing the brain, and a spine or back bone, containing the principal trunk of the nervous system, commonly called the spinal marrow: they have red blood. This division comprises the mammalia, (or animals that suckle their young,) birds, reptiles, and fishes.

2d, *Molluscous.*—Animals in this division have no internal skeleton: the muscles are attached to the skin, which, in many species, is covered with a shell. The nervous system and viscera are composed of detached masses, united by nervous filaments; they possess only the senses of feeling, taste, and sight; but many species want the latter. They have a complete system of circulation, and particular organs for respiration. Animals with bivalve,

---

* In the Museum at the *Jardin des Plantes* in Paris, there is a large specimen of two fossil fish, which are supposed to have been destroyed and covered with mineral matter, when one of them was in the very act of swallowing the other; but an inspection of the specimen inclined me to infer, that the two heads had been pressed together by the incumbent weight of stone deposited upon them.

univalve, or with chambered shells, belong to this division; but many molluscous animals have no shell.

3d, *Articulated.*—To this division belong worms, crustaceous animals, and insects: their nervous system consists of two long chords, ranging along the body, and swelling out in different parts into ganglions and knots. Worms having their bodies composed of rings, are called annelides; they have red blood: some species inhabit a calcareous tube, supposed to be formed by exudation.

4th, *Radiated*—comprises all the animals which were by former naturalists called zoophytes, or animal plants, as the corallines, &c. which were long mistaken for marine vegetables. In animals of this division, the organs of sense and motion are disposed circularly around a centre or axis. They have no distinctly marked nervous system, and the traces of circulation in many species can scarcely be discerned. Many of the animals in this division have no power of locomotion, as madrepores and encrinites. Others, as the echinus, possess a very complex organization, and the power of moving from place to place on their spines, which serve them for feet.

In describing the order in which the organic remains belonging to each of these grand divisions are distributed through the different classes of rocks, it will be more convenient to begin with the lowest.

Radiated Animals, such as encrini and madrepores, have left their remains abundantly dispersed through rocks of the transition series: many of the strata appear almost entirely composed of their mineralized exuviæ, but generally in a broken state. The chain coral occurs occasionally in transition limestone. Other genera of radiated animals occur in the more recent formations of limestone, but seldom in sufficient abundance to compose nearly the whole mass of a stratum. This is the more remarkable, as coralline animals are forming extensive calcareous rocks in our present seas. Some genera and species of radiated animals which abound in transition rocks, have not left their remains in any of the upper strata; hence it might be inferred that they had long been extinct. In some instances the inference is not correct; the *Madrepora stylina*, so common in transition limestone, is entirely wanting in the secondary and tertiary strata; but a living animal of this species has recently been discovered in the South Seas. The pentacrinus, which is chiefly distinguished from the encrinus by its pentagonal stem and branches, makes its first distinct appearance in the lias, but is not frequently met with in the upper strata, and disappears entirely in the uppermost formations: hence it was long supposed that the species was extinct. A living pentacrinus has lately been discovered in the West Indies, and its stem and branches in a perfect state have been sent to this coun-

try; and still more recently a living pentacrinus was found in the Cove of Cork. See pl. 8, fig. 17.

The genus echinus makes its first appearance in the midst of the secondary strata, and various species are continued into chalk, which abounds with remains of this animal in high preservation. It may be remarked, that scarcely any calcareous stratum abounding in marine organic remains has been examined, in which remains of some species of radiated animals may not be found.

Articulated Animals.—Some species of worms (annelides) inhabiting tubes, have left their remains in the upper secondary, and tertiary strata: remains of crustaceous animals (crabs, &c.) are not numerous in the upper secondary strata, where they first occur; but they are more common in chalk and the tertiary beds of clay covering chalk. One of the very first inhabitants of the globe appears to have been a crustaceous aquatic animal, called in England the Dudley fossil, from its being first noticed in the transition limestone near that town. Its more appropriate name is the *Trilobite,* from the three parallel lobes or divisions of the body, with ranges of transverse ventral fins, somewhat similar to those under the tail of a lobster. The largest species are found in the slate quarries at Angers, in France. A specimen in my possession, from that place, measures seven inches in length: the body has taken the flat form common to almost all fossils found in slate, (see Plate 5;) it scarcely rises more than one-third of an inch above the surface of the slate; the upper slate contains the impression or mould of the animal. To this species Guettard has given the name of *Ogyges,* from its occurrence among the most ancient rock formations that contain vestiges of organic life.

The remains of winged insects have sometimes been found in the secondary strata in England, particularly in the calcareous slate of Stonesfield, Oxfordshire, where numerous impressions of the elytra, or hard cases which cover the wings, of coleopterous insects occur.* Professor Buckland very ingeniously conjectures that these winged insects might serve as food for the flying lizards (Pterodactyli) that are found in the same strata, and were cotemporaneous with them. Of all the four grand divisions of the animal kingdom, the *Articulated* has supplied the smallest number of fossil organic remains.

Molluscous Animals.—Shells of these animals, chiefly bivalves, occur in the limestones of the transition series; but the number of the species is comparatively small. Some chambered shells, particularly orthoceratites, are found in transition limestone.

In the secondary strata that cover the transition series, shells of molluscous animals, both bivalves and univalves, are more abundant, and the number of the species is greatly increased.

* The wing of an insect, about the size of that of the dragon-fly, was found delicately preserved in a nodule of ironstone, from the coal-fields of Shropshire. It is in the Mantellian Museum at Brighton.

It is in the lower strata of this series that chambered shells, such as nautilites and ammonites, first become numerous; some species are continued into the chalk strata, but no ammonites are found in the strata above chalk. Trochiform or top-shaped spiral univalve shells first appear in the lower part of the secondary series, but become more numerous in the upper part of this series. In the tertiary strata above chalk, the species of univalve shells greatly exceed that of the bivalves: in the lower strata, the reverse is the case. We may further remark, that, as the tertiary strata are the most recent of regular rock formations, so the organic remains which they contain, bear a closer resemblance to the shells of molluscous animals living in our present seas, than what are found in the more ancient strata. Some of the shells in the upper part of the tertiary strata, appear, indeed, to be identical with those of existing species.

The different classes and orders of molluscous animals that have left their remains in the lower and the upper strata, doubtless possessed each the peculiar organization that best enabled them to exist and multiply under the peculiar condition of our planet, that was cotemporaneous with the epoch of their creation. When this condition was changed, their numbers were diminished, or they disappeared entirely, and were succeeded by different races, with an organization adapted to other modes of existence, and to the new circumstances in which they were placed. Such are the legitimate inductions we appear justified in making, from the organic remains in the different strata. The further consideration of this interesting inquiry will be resumed in the succeeding chapters.

Vertebrated Animals are arranged under four classes:—Fishes, reptiles, birds, and mammiferous animals. Remains of fishes are exceedingly rare in transition rocks; but they appear decidedly in the lower secondary strata. The entire bodies are sometimes well preserved; and the bones, scales, teeth, and vertebræ are met with occasionally in almost all the strata that contain fossil shells, whether secondary or tertiary. Many of the fossils bear a close resemblance to species at present existing, either in the ocean or in rivers.

The bones and entire skeletons of reptiles allied to the saurian or lizard class, occur in the lower part of the secondary strata, and are very abundant in a dark argillaceous limestone called lias, and in the beds of clay that are over it. These animals are many of them different from any known existing genera: they were inhabitants of the ocean, and furnished with paddles instead of feet.* In the upper secondary strata, between the lias and chalk, the remains of other saurian animals, closely allied to living species of

* For an account of these large saurian animals, see Chapter 13.

crocodiles and lizards, are fully developed: they had feet, and were evidently amphibious. Of the saurian animals in this series, that called the iguanodon, discovered by Mr. Mantell near Cuckfield, in Sussex, is the most remarkable for its size; the length exceeding eighty feet, and the thickness of the body being equal to that of the elephant. It is supposed to have been herbivorous. It closely resembles in structure the iguana, a native of America and the West Indies.

Fossil remains of birds are extremely rare in the secondary strata; they are more common in some of the tertiary beds. The footmarks of birds have recently been discovered in sandstone of the secondary formations, both in Europe and the United States of America; they belong chiefly to the order of Grallæ or Waders: this indicates that they inhabited marshes or the sea shore. Remains of flying lizards have been discovered in a fossil state in Germany, and very recently in Oxfordshire and Dorsetshire: these were at first mistaken for the bones of birds.

Vertebrated animals of the highest class, the mammalia, occur in the tertiary strata, and in ancient beds of gravel and clay. Cetaceous animals, allied to the whale and seal, have been found in some of the tertiary strata; but they are by no means common. The bones of herbivorous land quadrupeds occur in the upper part of the tertiary beds, or what may be regarded as the latest geological formations: they are more frequently found in beds of clay and gravel than in the solid strata. Cuvier has ascertained the existence of fossil bones belonging to about seventy species of mammiferous quadrupeds, in the tertiary strata near Paris. Nearly forty of these are of extinct species, and several of them belong to extinct genera. A very considerable number of the large fossil bones belong to the different genera and species of the order named by Cuvier *Pachydermata*, or thick-skinned non-ruminant animals; as the elephant, the mastodon, the tapir, the hippopotamus, the rhinoceros, and the palæotherium. As these bones are very abundantly found in many countries in northern Europe, the fact proves either that the animals were natives of cold and temperate climes, or that the temperature of the earth has decreased. The entire body of an elephant imbedded in ice, in Siberia, was found in the year 1799. Its skin was covered with two kinds of coarse hair and a soft fur beneath, which affords almost certain proof that the animal was an inhabitant of a cold climate, or at least of one in which the winters were severe. A similar defence against cold is provided for terrestrial quadrupeds that inhabit cold countries, but is never observed in tropical climates, except in mountainous regions that have a low temperature. The author's attention was directed to this subject many years since; and in his "*Observations on the Effect of Soil and Climate on Wool,*" he has stated instances of English long-woolled sheep casting their

fleece in hot climates, and being clothed with short coarse hair, like bristles. Bishop Heber, in his travels in the Himalayan mountains, mentions a species of elephant which he saw there not larger than an ox, and "as shaggy as a poodle." He further states, "that English dogs, brought to these mountains, in a winter or two acquire the same short, fine, shawl wool, mixed with their own hair, which distinguishes the indigenous animals of the country: the same is in a considerable degree the case with horses." The fossil elephant that was once a native of Europe, according to Cuvier, differed as much from the Asiatic or the African elephant, as the horse differs from the ass. Bones and teeth of extinct species of carnivorous quadrupeds most frequently are found in caverns, intermixed with bones of herbivorous animals in a broken state. Since the time that fossil bones have been examined by naturalists who have attended to comparative anatomy, no vestiges of human remains have been discovered; nor have any of the bones of the animals which approach nearest to man in structure, the *Quadrumana* or monkeys, been yet found with those of the more ancient inhabitants of the globe.* The vast diluvial beds of gravel and clay, and the upper strata in Asia, have, however, not yet been scientifically explored; and both sacred and profane writers agree in regarding the temperate regions of that continent, as the cradle of the human race.†

Vegetable Petrifactions.—The remains of vegetables found in different strata afford interesting information respecting the ancient condition of our planet, which we could not have obtained from animal remains alone. The animal remains found in the transition rocks are almost exclusively marine; hence we could not have inferred, from these remains alone, that any portion of the globe was dry land when these rocks were deposited. In some of the slate rocks, however, a few remains of terrestrial

* Since the former edition of this work, the jaw-bone of a species of ape has been found, with fossil bones of other mammalia, in the upper tertiary beds in the south of France. The age of the remains of human bones in caverns in France and Germany, (which will be noticed in a succeeding chapter,) is still undetermined.

† It has been conjectured, that the bones of man are more fragile and perishable than those of land quadrupeds; but this is contrary to experience; for it has been well observed by Cuvier, that the bones of men left on the field of battle with those of horses, are as well preserved as the latter, making allowance for the difference of size. Neither is there any essential difference in the chemical constituent parts of human bone from those of other animals of the class mammalia. Dry bones, according to Berzelius, contain as under:—

	Human Bones.	Human Teeth.	Ox Bones.	Ox Teeth.
Cartilage, - - -	33	—	33	3.5
Phosphate of lime, - -	51	85.3	55	81
Carbonate of lime, - -	11.5	8	9	7
Fluate of lime, - - -	2	3.2	3	4
Phosphate of magnesia, -	1.2	1.5	2	3
Soda and muriate of soda, -	1.3	2	2	2

plants, analogous to ferns, occasionally occur, which indicate the existence of islands or tracts of land at that remote epoch. In the strata of sandstone and shale, which alternate with coal and cover transition rocks of marine origin, the remains of terrestrial vegetables are abundantly distributed, and those of marine animals disappear entirely in most of the beds; the part formerly covered by the sea had, therefore, become dry land, with rivers, lakes, and marshes, on which the plants had grown, or were deposited. Again, at a subsequent period, the dry land and its vegetation became buried under a deep ocean, that deposited numerous calcareous beds, filled with shells and remains of marine animals, but occasionally containing a few broken fossil remains of terrestrial plants, which had probably been carried into the ocean by the rivers of distant countries. In the upper strata, the alternations of marine and fresh-water formations are distinct and frequent.

It appears that a progression from lower to higher forms of organic structure, takes place in the vegetable as well as in the animal kingdom, as we ascend from the lower to the upper or more recent strata.

I will endeavor to state this intelligibly to the geological student, who may at present be unacquainted with vegetable physiology, avoiding technical expressions as much as the subject will admit of.

Vegetables of all kinds may be arranged under two grand divisions—*Cellular* and *Vascular.**

Cellular—without regular vessels, but composed of extremely minute cells or vesicles. Confervæ, lichens, fungi, algæ or sea weed, and mosses, belong to this division. In some of these families there are no apparent organs of fructification.

Vascular.—Plants of this division, beside the cells of which cellular vegetables are composed, have tubes or vessels which form organs of nutrition and reproduction. According to the arrangement of these organs, and their number or complexity, vascular plants may be divided into the following classes, and each class contains distinct families:

1. Without perfect flowers, the organs of fructification concealed (*cryptogamia.*) To this class belong, in the fossil state, gigantic ferns, equiseta, (*horse tail,*) and other plants allied to ferns.
2. With flowers, the seeds naked or without capsules. To this class belong the family of cycas and coniferæ or firs. This class is denominated phanerogamia gymnospermous.

---

* For a full and clear description of the cellular and vascular tissues of vegetables, see Prof. Henslow's Physiological Botany, Chapter I.

3. Flowering plants with one cotyledon: phanerogamia monocotyledonous. It comprises water lilies, palms, lilies, and canes.
4. Flowering plants with two cotyledons; this comprises all forest trees and shrubs: phanerogamia dicotyledonous.

None of the families of plants, but those in the last class, have the true woody structure, or produce perfect wood, except the coniferæ or firs, &c.; but the wood of these, differs from true dicotyledonous wood.

In tracing the distribution of vegetables through the different classes of rock, we shall find only the lowest or simplest forms of organization, in the most ancient formations.

1. The lowest transition slate contains occasionally impressions of algæ or sea weed; but, considering the frail texture of the cellular plants, we cannot expect the forms to be well or abundantly preserved in rocks, which have probably been subjected to heat, and various disturbing agents. A few fronds, or leaves of ferns, have been found in some rocks of this class.
2. The upper transition beds of coal-measures abound in vegetable remains of the lower classes of vascular plants, and consist chiefly of families in which the organs of fructification are imperfectly developed; such as ferns, the equisetum or horse tail, the lycopodium or club moss, and of extinct species allied to these families or to coniferæ; the Lepidodendron, Sigillaria, and Stigmaria.* A few coniferæ also occur in the coal-measures.
3. The secondary strata contain chiefly remains of ferns, of the cycas, and of the Coniferæ.
4. Tertiary strata contain fossil plants of the more perfect classes, which are rarely, if ever, found in the secondary strata. Some of the most recent tertiary beds contain remains of trees analogous to what now flourish in Europe. Palms occur in tertiary, and occasionally in secondary strata.

The above brief outline of the distribution of fossil vegetables through the transition, secondary, and tertiary formations, shows a successive progression from the lower to the higher order of organic structure—from plants in which there are no distinct organs of fructification and reproduction, to others in which these organs are but obscurely developed; and, lastly, to plants producing flowers, fruit, and seed, with a woody structure like that of existing forest trees and plants. The study of fossil Botany is

* As some of the families of plants here named are extinct, and others are only known to the scientific botanist, the reader is referred to Dr. Buckland's Treatise, Vol. II, for plates of the following families: Pl. 55, figs. 1, 2, 3, the Lepidodendron; Pl. 56, figs. 1, 2, Sigillaria; figs. 8, 9, 10, 11, Stigmaria; Pl. 58, Cycas; Pl. 59, Zamia; Pl. 60, Fossil Cycadites from the Isle of Portland.

still in its infancy; from fifty to sixty thousand species of living plants have been named, but only five hundred species of fossil plants have yet been described. The characters of fossil plants are chiefly determined by the cortical impressions on fragments of the stems, as the entire plants are never found in the fossil state. Of those fossil plants which are analogous to existing families, it is observed that they are of a gigantic size, which the living families never attain, except in tropical climates.

Both vegetable and animal fossil remains appear to establish the fact, that there has been a successive progression from lower to higher forms of organic structure, from the most ancient geological formations to the most recent; or, we might say, from less to more perfect classes and orders. We must not, however, measure perfection of structure in animals by complexity of form, but by the number and perfection of their senses. Animals without heads and eyes, or the free power of locomotion, such as corallines and encrinites, required an infinity of tentacula, or arms, to enable them to feel and seize their prey; but this multiplicity of limbs, is a proof of their inferiority to the classes that have eyes, and the power of locomotion. Some species of caterpillars are said to have five thousand muscles to enable them to move their legs; but a comparatively small number suffices for the rapid motion of birds and terrestrial quadrupeds. If, therefore, we estimate perfection in animal life by the number and perfection of the organs of sense, and in vegetable life by the distinct organization of the organs of fructification and reproduction, we may safely admit a progressive succession from lower to higher orders, as we ascend from the ancient to the most recent strata. Of this fact, organic remains afford a mass of positive concurrent evidence, that cannot be refuted by negative arguments. We are told, that the bed of the sea has not been dredged, to discover what species of animals have existed in former ages. The geologist can have no need of such an operation. If the bottom of the sea has not been dredged, it has been laid bare, and is now exposed over an extent equal to that of the habitable globe; for every island and continent has formed part of an ancient bed of the ocean, and that not only once, but repeatedly and at distant epochs. This extended surface of the bed of the ancient ocean, is exposed to the examination of thousands of observers in every degree of latitude not covered by polar snows. These examinations have hitherto confirmed the position (taken with certain limitations) that a succession of higher orders of organic forms, both in the animal and the vegetable kingdoms, may be traced from the most ancient rocks in which these remains appear, through the different classes of rock, until we ascend to the most recent, which contain remains of animals analogous to existing species. All, or nearly all, the instances that

have been cited of animals of the higher classes being found in ancient strata have proved, on further examination, to be fallacious; yet when we consider what disturbing causes have acted on the crust of the globe, it need not appear surprising, if recent species of animals should sometimes be found buried in the lower rocks: this, however, would not affect the present question. It must be admitted, that animal remains belonging to higher divisions sometimes occur among ancient strata, where they were at first supposed not to have a place; but these exceptions, if duly considered, strongly confirm the position here advanced. Thus, from the first appearance of animal remains in the transition series, to the termination of the coal-measures, comprising a total depth of several miles of strata, we meet almost exclusively with the remains of the two lower animal divisions, the molluscous and the radiated; beds of vast thickness seem wholly composed of their calcareous fragments. It has been found, that remains of the vertebrated class occasionally occur with them; but these remains always belong to the lowest order, fishes. In the whole of the secondary strata, we first meet with the lowest order of mammalia, cetaceous animals; thus evidently proving that there was a constant progression from lower to higher forms of organic structure, which terminated with man. The subject will be farther considered. (See Chap. XV.)

The conclusions to be drawn from fossil plants are in many respects less satisfactory than those from animal remains, because fossil plants are scarcely ever found entire; portions of the stem, leaves, and in some instances seeds only, are offered to our observations. The cortical impressions on the stems are longitudinally striated and jointed like reeds, in the family of the equisetum. In plants of coniferæ, lycopodia, and families allied to them, the cortical impressions are rhomboidal, like scales, or contain rounded scars or impressions made by the footstalks or petioles of leaves growing out of the stem. The stems are most frequently more or less flattened, except in the coniferæ, and families in which the stem approached to a woody structure, as in the stigmaria, in which the pith is always discernible.

In fossil vegetables, the original vegetable matter is often so completely removed, that no trace of it is visible, and the stem appears converted into ironstone, sandstone, or chert. In some instances, the surface of the stem is black and carbonaceous, and all the inner part is mineralized. Sometimes, even when the stem is completely silicified, the vegetable organization is still perceptible, and some traces of the vegetable principles may be obtained by distillation.

GEOLOGICAL INFERENCES FROM FOSSIL ORGANIC REMAINS.

1. If an extensive rock or stratum be found to contain exclusively the remains of marine animals, we may safely infer that such rock or stratum has been formed or deposited at the bottom of an ancient ocean, whatever may be its present elevation above the sea.

2. If such marine remains are occasionally intermixed with remains of terrestrial vegetables, we may infer that there was dry land, covered with vegetation in the vicinity, at the epoch when the stratum was deposited.

3. If the stratum contain exclusively the remains of fresh-water animals, or the remains of land animals or plants, we infer that it has been deposited at the bottom of a fresh-water lake, or in the bed of an extensive river.

4. If the stratum contain an intermixture of marine and fresh-water animals or plants, we infer that it was deposited in an estuary, which had been alternately covered with salt and fresh water.

5. From the abundant remains of fossil vegetables allied to tropical plants, found in various regions remote from the equator, we infer that the ancient temperature of the globe was much higher than at present. Fossil animal remains also tend to establish the same conclusion.

6. If it be ascertained that some strata contain exclusively certain species of organic remains, and that such remains are neither found in the strata below nor above, we are enabled to identify such strata with the strata in another district, that contain similar remains.

OBSERVATIONS.

With respect to fossil conchology the author is inclined to believe, that the attempt to identify the strata of distant countries by the isolated occurrence of any particular species of shell, has been carried farther than a sound induction from facts or analogy would warrant. His opinion on this subject, given in the second edition of this work, he will here insert: "It may be doubted whether the occurrence of similar organic remains is sufficient to identify strata in distant parts of the globe; for could we admit that strata are universal formations, and extended from the frozen to the torrid zone, it seems more than probable, that the animals which lived on any one particular stratum would be of very different species in different latitudes."—We know so little respecting the forms or habits of the animals classed by the conchologist, that we are far from certain whether many shells which he regards as belonging to different species, or even genera, are not mere varieties of form, occasioned by difference of age or situation. Such a change is ascertained to take place by age in shells of the genus *Cypræa*.

In animals like the mollusca, which have no internal skeleton to determine their form, the construction of the external shell may probably admit of considerable variation under a change of circumstances. Few conchologists, excepting M. D'Avilla, have made accurate observations on the living animals inhabiting oceanic shells. His interesting work, entitled "*L'Histoire Naturelle éclaircie dans une de ses parties principales, la Conchologie; et augmentée de la Zoomorphose, ou Répresentation des Animaux à coquilles, avec leurs Explications,*" presents us with some truly extraordinary forms of molluscous animals, of which we could not have had a remote notion from the mere study of the shell.

In strata belonging to one formation in adjacent districts, the existence of certain shells may be of use in identifying any particular bed where its continuity with other beds of the same kind cannot be traced; and in distant countries where we find the same remarkable species of shell associated with any other remarkable species in considerable numbers, it may serve to identify a particular rock formation, where the mineral character of the rock may be very different from that in which the observer has been accustomed to meet with them. The occurrence of a considerable number of gryphææ, the *Gryphæa arcuata*, in a bed of blue clay in the mountains round the Lake of Annecy, in Savoy, served the author as a key to discover to what formation the calcareous strata belonged, when their mineral characters would have indicated a more ancient series.

CHAPTER III.

ON THE MINERAL SUBSTANCES THAT COMPOSE THE CRUST OF THE GLOBE; AND ON THE STRUCTURE OF ROCKS.

The constituent Elements of the simple Minerals that compose Rocks.—The Physical Characters of simple Minerals composing Rocks.—Explanation of the Terms employed in describing the internal Structure of Rocks, and the external Structure of Mountain Masses.—Sedimentary Depositions.—Distinction between stratified and stratiform Rocks.—Joints in Strata, called Slines and Cutters.

The most careless observer can scarcely fail to notice, that the mineral substances which occur on the surface of the globe, differ from each other in density, hardness, color, and other sensible qualities. Indeed, the different varieties of stone appear at first so numerous, as to render it difficult to become acquainted with them: but, however numerous these varieties may be thought, the simple minerals which compose rocks or strata are very few, and the elementary substances of which each of these minerals is formed, are still fewer.*

The elementary substances of which the solid matter of our globe is composed, are the *Earths,—silex, alumine, lime,* and *magnesia.* The *Metals,—iron* and *manganese.* The *Inflammable Principles,—carbon* and *sulphur;* and the *Alkalies,—potash* and *soda.—Muriatic* and *Phosphoric Acid* occur also in the mineral kingdom. The newly discovered earths and alkalies, and metallic ores cannot be regarded as forming essential constituent parts of rocks: they chiefly occur in veins. The four earths above enumerated, together with iron, compose nineteen parts in twenty of the known solid matter of the globe. The earths, when pure, are infusible, except at an intense heat; they are nearly insoluble in water at the common temperature: when pure, they are white or colorless. Though the earths are infusible when pure, if they are combined in certain proportions,

* The mineralogist and the geologist consider those minerals as simple and homogeneous, which present no difference of qualities to our senses throughout the mass, although the chemist may discover that such minerals are composed of two or more elementary substances. Thus, limestone or marble is regarded as a simple substance, though chemistry has discovered that it contains, in every 100 parts, lime 57 parts, and carbonic acid 43. It is the latter which is expelled from it by burning; a process which is well known to make the stone lighter, and to render it caustic; in which state it is called quicklime. Nor do the researches of the chemist end here: the two substances, quicklime or pure lime, and carbonic acid, are themselves compounds: the former, lime, is a compound of a metallic substance called calcium, united with oxygen; the latter, or carbonic acid, is composed of oxygen and carbon or charcoal.

they may be fused with facility at a comparatively low temperature.

Silex, or *Siliceous Earth*, exists nearly pure in large masses, forming minerals, and even entire rocks, as rock crystal, quartz rock, and flint: it communicates a great degree of hardness to all rocks or stones, in which it enters in a large proportion. Such stones are denominated siliceous: they resist the point of a knife, or scratch glass, and are infusible if unmixed with other earths. In its combinations with other earths, silex appears to act as an acid. More than one half of the crust of the globe is composed of siliceous earth, either pure or combined. In some thermal waters, siliceous earth occurs either in a state of minute division or in solution; and the waters of the boiling springs, or geysers, in Iceland, deposit siliceous incrustations of considerable thickness.

Alumine, pure argillaceous earth, (Lat. *argilla*, Fr. *argille*,) is a substance which, in a mixed state, is well known; but pure unmixed clay is one of the rarest substances in the mineral kingdom. This earth is soft, smooth, and unctuous to the touch; it strongly absorbs water, where it exists in the proportion of thirty per cent.: it communicates in some degree these properties. Such rocks are called argillaceous: they generally contain a notable portion of iron, which appears to have a greater affinity for this earth than for any other.*

Lime (Lat. *calx*, Fr. *chaux*) is a well-known earth combined with carbonic acid, in which state it forms limestone, marble, and chalk: these only differ from each other by different degrees of hardness or of crystallization. Mountains composed of lime are denominated calcareous. When lime is united with sulphuric acid, it forms the stone called gypsum, which is softer than limestone, and does not, like it, effervesce with acids. Calcareous earth mixed with common clay forms marl.

Magnesia has rarely been found pure in a native state. It enters into the composition of some of the primary rocks, to which it generally communicates a soapy feel, a striated or striped texture, and sometimes a greenish color. It occurs also in various limestones in different proportions.

Iron appears to be more abundant than magnesian earth: it forms a constituent part of numerous rocks and stones; to it they

---

* Though alumine or pure clay communicates a soft quality to most stones of which it forms a principal constituent part, a very remarkable exception to this is offered in adamantine spar and the sapphire, which nearly equal the diamond in hardness. Klaproth, one of the most laborious and eminent chemists of the present age, has analyzed these stones: the former contains 90 parts in the 100 of pure clay; the latter 95 parts in the same quantity. "What a high degree of cohesive power (he observes) must nature command, to be able to transform such a common substance as clay (aluminous earth) into a body so eminently distinguished and ennobled as the sapphire by its hardness, brilliancy, and its resistance to the action of fire, of acids, or the effects of all-destroying time!"—*Klaproth's Essays.*

most frequently owe their color: the earths, when pure, are white. Iron, when in combination with the earths, is, like them, an oxide, or a metal united with oxygen. To the presence of iron the increase of specific gravity in all stones or earthy minerals may be attributed, if it much exceed 2.5, or approach 3: in other words, if they are nearly three times heavier than an equal bulk of water. Gems, and the earths barytes and strontian, are exceptions; but these never form entire rocks. The presence of iron not only increases the weight and darkens the color of numerous rocks and stones, but is one principal means of their decomposition, for iron exists in stones in two states of oxygenation, as the black or the red oxide; and when the former is exposed to air and moisture, it absorbs a greater portion of oxygen, and is converted into a brown ochrey incrustation, which peels, and exposes a fresh surface of the stone to a similar process.

Manganese, in a state of oxide, occurs in a few rocks, to which it generally communicates a dull reddish color inclining to purple, and a peculiarly dry and burnt-like appearance.

Sulphur, though found in considerable masses, cannot by itself, be regarded as a constituent part of rocks; but when it is combined with oxygen, forming sulphuric acid, it unites with lime, and forms the well-known mineral gypsum or plaster-stone.

Carbon, or *Charcoal*, enters as a constituent part into many of the slate rocks, to which it generally communicates a dark color: it forms also regular beds of considerable thickness, being the principal constituent part of coal. Carbon, combined with oxygen, forms carbonic acid or fixed air, which is combined and solidified in all limestone rocks in a proportion exceeding two fifths of the whole weight. As carbon exists in such a large proportion in even the oldest limestones, we may regard it as a constituent element, and not as a substance derived from the vegetable kingdom. For whence did the vegetables themselves derive their carbon?

Potass and *Soda.*—These alkalies occur in minerals which compose parts both of primary and volcanic rocks; but the proportion is so small, that they would scarcely deserve the attention of the geologist, did not the latter alkali, soda, exist in such abundance in the waters of the ocean and in rock salt. Pure sea salt, or rock salt, contains nearly 53½ parts of soda, 46½ muriatic acid or chlorine.

Muriatic acid, combined with soda, is the only state in which this acid forms a constituent part of any rocks we are yet acquainted with; except in some volcanic rocks, where it may be regarded as accidental.

Phosphoric acid, combined with calcareous earth, is a principal constituent of animal bones: it occurs also in a few limestone beds, which are supposed to have derived phosphoric acid from

the decomposition of animal matter. This acid is of very rare occurrence in the mineral kingdom.

The above elementary substances, either separately or combined, form all the simple minerals of which rocks are composed. A knowledge of these minerals, and their different intermixtures and combinations, can only be learned by an examination of specimens: they are, however, far from being numerous; and a short description of each is necessary in an introductory treatise.

The most important simple minerals composing rocks, are quartz, felspar, mica, talc, chlorite, hornblende, serpentine, limestone, and slate.

Quartz is one of the hardest minerals of which mountain masses are composed: it gives plentiful sparks with steel; it breaks with a smart stroke of the hammer; the surface of the fracture in crystallized quartz is conchoidal, in uncrystallized, splintery: the lustre is vitreous. Crystals of quartz, or rock crystals, as they are commonly denominated, have different degrees of transparency: the blue varieties are amethysts. The most common forms of the crystals are six-sided prisms terminated by six-sided pyramids; or, two six-sided pyramids united, forming a dodecahedron, whose faces are isosceles triangles. Uncrystallized quartz is seldom transparent, most frequently translucent, but sometimes opaque. Its colors are various shades of white, grey, brown, yellow, red, and green. It yields a phosphorescent light and peculiar odor when rubbed. Quartz is composed of siliceous earth, combined with a very small portion of alumine. It is infusible when unmixed, but with alkalies it melts easily, and forms the well-known substance called glass. It is not acted upon by any acid except the fluoric. Quartz exists in veins intersecting mountains, and it sometimes forms large beds, and even entire mountains, which are composed of this mineral in grains united without a cement, called granular quartz. Fragments or crystals of quartz are common in compound rocks. Grains of quartz form a principal constituent part of most sandstones. The milk-white pebbles in gravel are composed of quartz. Flint, chert, or hornstone, opal, chalcedony, and agate, are different modifications of siliceous earth, which, in their chemical composition, differ little from quartz. Combined with a large portion of alumine and iron, quartz loses its translucency and passes into jasper, which forms beds in primitive mountains, and is said to compose the substance of entire ranges of mountains in Asia.

Felspar, or *feld-spar*, (a name received from the Germans,) is a constituent part of numerous rocks. It is hard in a somewhat less degree than quartz, and is more easily broken. It is laminar, or composed of thin laminæ or plates, by which it may be generally distinguished from quartz. The crystals are most commonly four-sided or six-sided prisms, whose length is greater than

the breadth. It has a shining lustre. The colors are white, grey, milk-white, yellowish or reddish white, sometimes inclining to green. The red passes through various shades, from a pale to a deep red. Crystallized felspar is translucent. It may be melted without the admixture of alkalies, and forms a glass more or less transparent, which quality it derives from the lime or alkali that composes part of its constituent ingredients; but different specimens of this mineral vary, according to the analyses of the same chemist.

Silex - - -	63	—	74
Alumine - - -	17	—	14
Potash - - -	13	—	
Lime - - -	3	—	6
Oxide of iron - -	1	—	
Loss - - -	3	—	6

Others give the proportion of silex 46, alumine 24, lime 6.

The existence of potash, or the vegetable alkali, in felspar, is a fact deserving particular attention.* It may be owing to this circumstance that felspar is so frequently observed in a soft or decomposing state, although its hardness is little inferior to that of quartz when undecayed. Those felspars which are durable are probably free from potash. Felspar occurs in many rocks in a compact form, and constitutes the principal part of most porphyries, and of the lighter colored lavas. Compact felspar differs from hornstone, the latter being infusible without the addition of alkalies.

Mica derives its name from the Latin *micans*, glittering. It is known as the substance called Muscovy glass, and has a splendid lustre. It consists of very thin leaves or laminæ, which may be easily separated with a knife. The plates are elastic, by which it may be distinguished from the mineral called talc. The thin plates are transparent. The colors of the thick plates are yellow, grey, blackish green, white, and brown. The surface may be scratched with a knife: it melts into an enamel with the blowpipe: it is sometimes crystallized in six-sided prisms.

Talc nearly resembles mica in appearance. The plates are flexible, but not elastic: it is much softer than mica, and is infusible: its colors generally incline towards green, but it is sometimes a silver white: it has a soapy feel. *Chlorite*, which is

* It has recently been discovered, that, in some of the felspathic rocks, soda occupies the place of potash, and gives a slight change to the crystalline form: this variety some mineralogists are desirous of making a new species, and have proposed to give it the name of Cleavelandite; but geology and mineralogy are already too much burdened with unmeaning terms, and if a new name must be introduced, that of felsparite would be more appropriate, and convey an idea of its approximation to felspar.

nearly allied to talc, derives its name from *chloros*, the Greek word signifying green. Talc and chlorite pass by insensible gradations into each other, and in this state they supply the place of mica in most of the granitic rocks that I have examined in the vicinity of Mont Blanc. Chlorite is of a darkish dull green color; it has a glistening lustre; its structure is minutely foliated; it is soft, and rather unctuous. The constituents of these three minerals are,—

	Mica.	Talc.	Chlorite.
Silex - -	50	62	41
Alumine - -	35	2	6
Lime - -	1		1
Magnesia - -	2	27	40
Oxide of Iron - -	6	3	10
Water, and loss -	6	6	2

but these proportions vary in different specimens.

Hornblende, to which the French give the name of *amphibole*, forms a constituent part of many rocks, and appears to connect the primary with those which are of volcanic origin. It is of a black or dark green color: it is heavier, but less hard, than quartz or felspar: it may be scratched with a knife, and the color of the streak is a light green: it yields a bitter smell when breathed upon, and melts easily into a black glass. Common hornblende is often confusedly crystallized: it sometimes forms entire mountains, or slaty beds in mountains, and is very commonly met with in granular pieces, as an ingredient in compound rocks: when it becomes more abundantly and minutely disseminated in them, it forms what are denominated trap rocks, whose origin has greatly divided the opinions of geologists. Hornblende and the rocks to which it is most nearly allied contain as under:—

	Hornblende.	Basalt.	Obsidian, or volcanic glass.	Lava.
Silex - -	42	44	72	49
Alumine - -	8	16	12	35
Magnesia -	16	2		
Lime - -	9	9	sometimes	4
Oxide of iron -	23	20	2 with manganese.	12
Soda - -			6 with potash.	
Manganese -	1			
Water and loss				

Another mineral substance, called *serpentine*, from its spotted colors resembling the serpent's skin, will afterwards be described as forming entire rocks: it differs in composition from hornblende, by having a larger portion of magnesia, and less iron; it may perhaps be regarded as an intimate combination of hornblende with

talc or chlorite. Its component parts, as given by different chemists, are as under:—

Silex - -	45	29	45
Alumine - -	18	23	
Magnesia - -	23	34	33
Iron - -	3	4	14 with a trace of alumine.
Lime - -			6
Water and loss	11	10	8

From these analyses it is evident that the specimens vary in their component parts; in some, the proportions are almost the same as in hornblende; in others, they more nearly agree with talc and chlorite.

The intimate connection between hornblende and serpentine is now completely established; for hornblende is observed to be changed into serpentine, by contact with limestone in various situations. Serpentine sometimes occurs crystallized, and has received the name of diallage.

Limestone, (*Carbonate of Lime*,) however various in external appearance it may be, is, if pure, essentially composed of 57 parts of lime, and 43 carbonic acid; but in some rocks the limestone is intermixed with magnesia, alumine, silex, or iron. The specific gravity of limestone varies from 2.50 to 2.80. All limestones may be scraped with a knife. They are infusible; but when impure by an intermixture with a portion of other earths, they vitrify in burning. All limestones effervesce when a drop of strong acid is applied on the surface; and they dissolve entirely in nitric or muriatic acid. The specific gravity, hardness, and effervescence with acids, taken collectively, distinguish limestone from all other minerals.

Crystallized Carbonate of Lime (*Calcareous Spar*) occurs crystallized in a great variety of forms; the crystals break easily with the stroke of a hammer, and the fragments are always rhomboidal.

Vast mountains and extensive strata of limestone cover a large portion of many countries. The varieties of limestone will be described, as the rocks occur in the primary or secondary series. The different appearance of statuary marble and chalk is well known to every one. They are only different modifications of limestone, and are chemically the same. Magnesian limestone, sometimes called Dolomite, possesses most of the physical characters of common limestone, but contains various proportions of magnesia.

Gypsum, or *Sulphate of Lime*, is far less abundant than carbonate of lime; but it forms, in some situations, beds of considerable thickness and extent. Gypsum is generally of a color

inclining to white, and is sometimes snow-white. Common gypsum has a laminated or granular structure, and is sometimes compact. It is much softer than common limestone, and may be scratched with the nail; it does not effervesce with acids. Crystallized gypsum has the properties of common gypsum; it is frequently called selenite. The constituent parts of gypsum are lime 32.7, sulphuric acid 46.3, and water 21. A variety of gypsum which has no water in its composition, and hence called anhydrous, occurs in beds in the Savoy Alps; it is there combined with siliceous earth. It is much harder than common gypsum, and even than common limestone. The specific gravity of common gypsum varies from 2.16 to 2.28; that of anhydrous gypsum is from 2.80 to 2.90. Gypsum, under the name of plaster stone, is a mineral generally known.

Slate, improperly called by some geologists clay-slate, and by the old geologists argillaceous schistus, is well known,—at least the common variety used as roofing slate, which may be regarded as the purest form of this mineral.

The prevailing colors of slate are bluish or greenish grey: it has a silky lustre. Slate rocks have frequently a distinct slaty structure, and may even be split in two directions, which have an acute angle with each other; but some slate rocks have a compact structure, and will not admit of splitting. Slate yields to the knife: it is fusible into a black slag. The composition of slate is various: indeed, by many geologists it is not regarded as an homogeneous rock. Its composition has been given as under:—Silex 48, alumine 23, manganese 1.6, oxide of iron 11.3, oxide of manganese 0.5, potass 4.7, carbon 0.3, water 7.6. The quantity of carbon increases in the upper formations of slate, and it passes by a greater admixture of carbon into a soft, dark, slaty bed, denominated shale by the English miners. Slate is a very extensive formation, composing entire mountains in many alpine districts.

Basalt and compact lavas are classed by some mineralogists with simple minerals, but they are composed of three or more simple minerals closely united:—they will be afterwards described.

Some of the minerals here enumerated compose entire rocks; other rocks are composed of an intermixture of two or more simple minerals, either cemented together by another mineral substance, or the minerals are crystallized and united without a cement. The different modes in which simple minerals are found united together in rocks have given rise to the following terms:—

Granitic, composed of grains or crystals united without a cement, as in granites, and some sandstones.

Porphyritic, composed of a compact homogeneous rock, in which distinct crystals or grains are imbedded. The compact stone

is called the base, and sometimes the paste. The base of some porphyritic rocks is granitic; in this case some of the crystals are much larger than the rest.

Amygdaloidal, containing rounded or kernel-shaped cavities filled with mineral matter of a different kind.

Breccia is composed of angular fragments of rocks cemented together.

Pudding-stone consists of rounded stones imbedded in a paste.*

Fragments of stone broken from *simple rocks* display the structure of the internal parts. The face of the broken part is called the fracture. This internal structure may be denominated the mineral structure, and is either

Compact, without any distinguishable parts or divisions; or

Earthy, composed of minute parts resembling dried earth.

Granular, composed of grains.

Fibrous, composed of long and minute fibres.

Radiated, when the fibres are broader and flattish, and diverging.

Lamellar, or *Foliated*, composed of minute plates laid over each other.

Porous, penetrated by pores.

Cellular, or *Vesicular*, when the pores swell into rounded cavities, like bladders, as in some lavas.

Slaty, or *Laminar*, composed of straight parallel thin plates, or laminæ.

The structure of *compound rocks* may also be *Slaty*.

The external structure of rocks *en masse*, or considered as mountain masses, is as distinct from their internal mineral structure, as the shape of a building from that of the bricks or stones of which it is composed; though this distinction has been generally overlooked. The external structure of rocks, as forming mountain masses, may be

Stratified.

Stratiform.

Tabular, or in large plates.

Columnar.

Globular, or in spherical masses.

Massive, or *Indeterminate*, which includes all unstratified rocks that have no determinate shape.

Stratified.—Stratified mountains, or rocks, are those which are composed of layers of stone laid over each other, and divided by parallel seams like the leaves of a closed book. In these seams or partings, which divide the strata, there are frequently thin laminæ of soft earthy matter; but sometimes the surfaces of the

---

* When fragments of stone, whether angular or rounded, are large, and are imbedded in strata of indurated clay, sand, or sandstone, they are called *Conglomerates.*

upper and lower stratum are so closely joined, that it requires a considerable force to separate them. These layers are denominated strata: they extend through the whole mountain or mass, their length and breadth being much greater than their thickness. If the thickness of any stratum exceed two or three yards, it is more usually denominated a bed; and if it lie between beds of stone of a different kind, it is said to be imbedded. Strata almost always decline, or dip down to some point of the horizon, and of course rise towards the opposite point. A line drawn through these points is called the line of their dip: another line, drawn at right angles to this, marks the course along which the strata stretch out to the greatest extent; it is called the line of bearing. If a book be raised in an inclined position, with the back resting lengthwise upon the table, the leaves may be supposed to represent different strata; then a line descending from the upper edges to the table will be the line of dip, and their direction lengthwise will be the line of bearing; and the angle they make with the table will be the angle of inclination. Strata are, however, sometimes curved or bent in both directions, and are frequently broken; which makes it difficult to ascertain their true position.

Stratified rocks of sandstone, and beds of clay and marl, are generally admitted to have been deposited by the turbid waters of the sea, or of large rivers or lakes. These sedimentary depositions are arranged over each other in regular layers; the particles or fragments of which they are composed vary in size, and indicate the different states of agitation or repose of the waters from which they were deposited. Some strata appear to have been formed by chemical precipitation; and not unfrequently chemical precipitation and sedimentary deposition have taken place at the same time, and produced rocks of a mixed character.

Stratiform.—This structure has been considered synonymous with the stratified, but it will be useful to distinguish between them. Many masses of rock, which are evidently of igneous origin, occur divided into parallel planes, by seams or divisions which resemble those in regular strata; such planes have not been superimposed in succession, but are the result of refrigeration, or of a crystalline arrangement of the mass. Many unstratified rocks present in some parts a tendency to the stratiform structure, and have given rise to much controversy, as the stratified structure was once universally believed to be the result of successive sedimentary depositions. The distinction between *stratified* and *stratiform*, the young geologist will do well to bear in mind.

The *Tabular structure* consists of parallel plates of rock, separated by regular seams. This structure has often been confounded with stratification: it appears to be the result of crystallization, and is closely allied to the columnar structure.

The *Columnar* or *Prismatic structure* is peculiar to certain rocks, but chiefly occurs in the basaltic and volcanic class. Thick beds are divided into columns or prisms, which are most generally pentagonal. They sometimes form vast ranges of natural columns, as at Staffa, the Giant's Causeway, in Ireland, and in many volcanic countries. Sometimes the prismatic structure may be observed forming detached groups of columns and prisms: a group of columns on Cader Idris will be subsequently described. A group of basaltic columns, of similar form, and equally perfect, was observed by the author on the side of the volcanic mountain called Gravenaire, in Auvergne, at a small distance from the crater.

The *Globular structure* consists of globular masses, either detached or imbedded in rocks of the same kind: they are frequently composed of concentric layers.

The terms *Massive* or *Indeterminate* may be applied to all unstratified rocks that have no regular divisions. Many of the primary rocks, such as granite, porphyry, and serpentine, occur in masses of enormous thickness, which are broken by irregular fissures in every direction. Thick currents of lava, which have filled up hollows or valleys, are also indeterminate, as might be expected from their mode of formation. Sometimes rocks of granite and porphyry, and also of compact lava, present either a tabular or a columnar structure; but the structure is seldom so regular as in basaltic rocks.

OBSERVATIONS.

Besides the different modes of structure here enumerated, it is well known to quarry-men, that almost all beds of stone contain cracks or joints, which cross the stone in transverse directions, more or less regular. These joints appear in some cases to result from mechanical pressure, in other instances, where the faces of the joints are smooth, they may have been caused by contraction of the stone, combined with a tendency to crystalline arrangement. In some of the sandstone strata, in the Ashby de la Zouch coal-field, I have seen the joints occasionally coated with thin laminæ of lead ore, *galena.* Beds of coal are divided by transverse joints, called *slines* and *cutters,* into rhomboidal masses.

CHAPTER IV.

ON STRATIFICATION, AND THE RELATIVE POSITION OF ROCKS.

Strata and Geological Formations explained.—Various appearances presented by plane Strata.—Appearances presented by curved Strata, and errors respecting them.—Distinction between Strata Seams and Natural Fissures or Cleavages.—On the conformable and unconformable Positions of stratified and unstratified Rocks.—The Continuity of stratified Rocks broken by Valleys.—Longitudinal Valleys.—Transverse Valleys.—Lateral Valleys.—Denudations.—On the Elevation of Mountains and Mountain Chains.—On the Direction of Mountain Chains in the new and old Continents.—On vertical Beds in Mountains.—On the Devastation in Alpine Districts.—On the Passages in the Alps called Cols; and Observations respecting their Formation.—Different Ages of Mountain Ranges.

When we have ascertained what are the most common or prevailing rocks in a part of any country, and observed that any one stratum or rock which attracts our attention is in that part of the country invariably covered by a peculiar rock or stratum of a different kind, or invariably covers any particular stratum; we hence learn that there is a certain order of superposition, and we naturally feel desirous to know whether the same order is observable in every country where similar rocks occur. Thus, in the vale of Thames round London, there is, at the depth of a few feet under the surface, a dark colored clay, called London Clay, much intermixed in the lower part with beds of sand. If we bore through this clay, we shall find its average thickness to be nearly three hundred feet. When we have pierced through this, we invariably come to chalk;* and were we to continue to bore in the chalk, after piercing through many hundred feet of that rock, we should come to a stratum of sand or sandstone filled with green particles, and hence called Green Sand.

The observer, who had confined his researches to this part of the country only, would form a very erroneous conclusion, were he to infer that the outer crust of the globe was invariably composed of London clay, chalk, and green sand. But wherever similar beds occur together, they lie in the same order of superposition over each other. Thus the London clay is never found under the chalk or the green sand.

But it is not always necessary to bore through the upper beds to ascertain this order; for the different strata scarcely ever occur in a flat or horizontal position: they generally rise in a certain direction, and come to the surface, as represented in the section, Plate I, fig. 1. Now, by travelling over the strata from A to B,

---

* The lower clay is by some geologists denominated plastic clay. See Chap. XIV.

we come upon the outer edges 1, 2, 3, and may trace their order of succession as they rise from under each other. In ravines and the escarpments of mountains, and in the cliffs on the sea coast, we are also enabled to trace the position and order of succession of rocks. But to do this with tolerable correctness, we must have an accurate knowledge of stratification in all its various possible forms. However simple the principles of stratification may at first appear, this knowledge, when applied to practice, is not of such easy attainment as some may imagine; and for want of it, geologists of considerable eminence have fallen into the most egregious errors. A knowledge of stratification is indeed of far greater importance to the practical geologist, than an acquaintance with the minutiæ of mineralogy or conchology.

Though the word Stratum, in its original language, and by general acceptation in speaking of rocks, denotes a bed, it is convenient to restrict the term bed to a stratum of considerable thickness; for such beds are often subdivided into several distinct minor strata, and we cannot well describe a stratified stratum.

When a series of strata of a similar rock, are arranged with occasional intervening strata of rocks of another kind, which recur in different parts of the series, they are regarded as having been all formed nearly at the same epoch, and under similar circumstances; and such series are called by geologists *Formations.* Thus, the strata of shale, sandstone, and ironstone that accompany beds of coal, are called the *Coal formation.* Strata of different kinds, in which a gradation is observed into each other, and which contain similar species of organic remains, also constitute a *geological Formation.* The chalk with flints, the lower chalk without flints, the chalk-marl and the green sand under the chalk, are regarded as members of what is denominated the *Chalk formation.* The student, however, must be careful to distinguish the different meaning of a *rock formation,* as here described, and the formation of a rock: the latter term implies the mode of formation, or the agent by which the rock was formed or consolidated; whether by igneous fusion, as beds of lava; by deposition from water, as beds of clay and sandstone; or by animal secretion, as beds of coral.

In order to obtain a distinct idea of stratification in its simplest form, let the young geologist take a piece of pasteboard or thin wood, say twelve inches square: let him divide it in the middle into two equal planes, each twelve inches in length and six in breadth. Place one of these planes flat on a table with the shorter sides or ends facing the north and south; the longer sides will of course be at right angles, and face the east and west. Now, if one of the longer sides be tilted up,—say the western side, we may suppose the pasteboard plane to represent a stratum rising to the west and dipping eastward. The lengthwise direction of the

plane is called the *line of bearing;* and the declining direction is called the *line of dip*, which is at right angles to the line of bearing. The angle at which the stratum rises above the horizontal line or level, is called the *Inclination.* Suppose the western edge of the pasteboard plane is raised above the table, forming with it an angle of thirty degrees; then we say the direction of the stratum is north and south, its dip east, its rise of course west, and its angle of inclination thirty degrees. Simple as this appears, geologists of considerable eminence have made the most palpable mistakes in defining stratification. It has been said correctly, that, the line of dip being always at right angles to the direction or line of bearing, when the dip is given, the direction is known: but when it is further said, that, if the direction is given, the line of dip is given also, the assertion is erroneous; for let the above plane of pasteboard be again laid flat upon the table in the same direction, due north and south; and instead of tilting up the western edge, if we tilt up the eastern, we shall then have the same line of bearing as in the first instance, but the dip will be west instead of east.

It sometimes happens that a stratum, without varying its direction, may be so bent as to dip two ways in the same mountain, like the sloping sides of the roof of a church, or the letter V reversed, (Λ.) (See Plate I, fig. 2, stratum 4, and 5.) Place the two planes of pasteboard in a north and south direction, and raise them so as to make the upper edges meet; we shall then have the line of bearing north and south as before, and the dip east on one side and west on the other. The limestone strata at Dudley Castle Hill dip on each side of the hill as above described. (See Plate III, fig. 4, B.) When strata are bent on each side of a mountain, without being broken at the top; they are called saddle-shaped. A line traced on the surface of a country, to designate where the strata dip in opposite directions, has been called the *anticlinal* line, and should be introduced in all geological maps, when it can be conveniently ascertained.

Whatever may be the inclination of a stratum, its true thickness is measured by a line perpendicular to the upper and under surface.

If we take a number of similar planes of pasteboard of different colors, and lay the undermost a little inclined, and place another plane upon it, with the upper edge about an inch or more distant from that of the under stratum, and again lay the others in succession in the same manner; the uncovered ends of the planes will rise from under each other like a number of slices of bread and butter laid on a plate. These uncovered edges will represent the outcrop or crop of the strata, and it will be perceived how we may obtain a knowledge of an under stratum without sinking or boring, merely by crossing a country in the line of the

rise or dip of the strata. When strata are arranged in this manner, they are said to be in a conformable position. (Plate I, fig. 1.) It will naturally be enquired, whether the strata absolutely terminate where we find their outcrop? In some instances this is the case; but frequently the strata are bent or broken in the line of their rise, and the same stratum may crop out in one place, and appear again farther on in the line of its rise, as represented, Plate I, fig. 2. We must be particularly attentive to this circumstance, otherwise we may commit the most egregious errors in describing a country which we have travelled over, where there is no opportunity of seeing a section of the strata. Thus, in fig. 2, after passing over the beds 1, 2, 3, 4, and having no easy method of ascertaining the dip, we may again come upon the edges of the same strata 1, 2, 3, 4, and suppose them to be different and lower beds in the series. Ebel and many flying geologists have made this mistake.

In some instances we come suddenly to the termination of a whole series of strata, as in descending the Cotswold Hills into the Vale of Severn; the limestone called Roe-stone, of which they are principally composed, is not found on the other side of the valley, nor in any part of England to the northwest of it. Has this limestone ever extended farther westward? and if it have extended farther, by what cause has it been removed? These enquiries will be adverted to in a following chapter.

To return to our pasteboard planes, arranged as before described, with the edges rising from under each other in the conformable position. If we take another series of planes, and lay them flat over the outcropping edges of the conformable series, we shall then have the unconformable position represented, Plate I, fig. 3. Now, the strata that cover the coal measures and transition beds in England occur in this position; and the following important inference may be drawn from it, namely, that the under stratified rocks had been formed, and their strata broken and raised up, at a period which must have preceded the formation of the upper series by a considerable interval; for the lower series were evidently solidified, and afterwards in many instances broken, and the fractured edges of the strata levelled, before the upper strata were deposited upon them.

The most common error into which persons commencing the study of geology are liable to fall, is in mistaking the apparent for the real inclination of the strata. Plate I, fig. 4, will render this more intelligible than any description. It represents a portion of a stratified mountain, of which the strata have a considerable dip to the east. If the escarpment or section be made in the line of bearing, *c d*, the strata will appear to range from north to south, without any rise or dip, and would be described by a young observer as being horizontal. But if an opening or section

be made on the side parallel to the line of dip, as at *c c*, the true inclination will be seen. Any section made in a different direction to the line of dip will cause the inclination to appear less than the true one, and the line of dip will appear to vary from the true dip. The chances, therefore, are very great against a natural section made in a mountain, presenting the true dip and inclination of the strata. In fig. 4, Plate I, we see represented two sections of a hill, from which the loose materials are supposed to be cleared away, and the dip, direction, and thickness of the strata are exposed to view. The section from *d* to *c* in the line of bearing is sometimes called the *longitudinal* section, and that from *c* to *c* in the line of dip *the transverse section.*

Another error which the observer who does not attend to the dip and direction of the strata, may fall into, is, mistaking an under for an upper stratum. Suppose a hill to be covered with vegetable soil, and a quarry or pit was made in it near the bottom, as at *a*, Plate I, fig. 1, and the stone was discovered to be sandstone: if another pit was sunk near the summit at *b*, which cut into limestone, it might be supposed, because the limestone is met with at a higher level, that it lies over the sandstone stratum, when it is in reality below it. The young observer, who has not a clear notion of this, may be said not yet to have passed the *pons asinorum* of the geologist.

In calcareous mountains of vast magnitude, as those in the Swiss and Savoy Alps, the enormous beds of limestone are often intersected by regular seams, which cut through the whole bed in a direction nearly perpendicular to that of the true strata seams, or make very oblique angles with them. These partings or seams are sometimes nearly vertical, when the strata are almost horizontal. The cliffs and escarpments of these mountains being lofty, and much exposed to the action of the atmosphere, the vertical seams enlarge, and are often more conspicuous than the strata seams; hence, without great attention, the observer may describe the strata of a mountain as being perpendicular, when in reality they are nearly horizontal. To add to the difficulty, it very frequently happens that a calcareous deposition, like a coat of plaster, covers the face of a rock: this has been formed by moisture running over the surface, and depositing calcareous particles upon it. This deposition sometimes conceals the partings or seams of the stratification as completely as a coat of plaster covers the rows of brick in a building. The vertical seams or partings are also sometimes open, and form parallel ridges, which efface the appearance of the strata seams in one part of a rock, but not in the other; and in such instances we have a mountain mass in which the strata are apparently partly horizontal and partly vertical. (See Plate I, fig. 5.) Inattention to this circumstance, I am

convinced, has sometimes deceived the eye of M. Saussure, one of the most diligent and accurate of observers.

The regular partings or cleavages in many slate rocks which intersect the beds, nearly at right angles to their dip or inclination, (see Plate III, fig. 1, *d d*,) have often been mistaken for strata seams, and have led geologists of some eminence to draw very erroneous inferences. The thick beds of transition or mountain limestone which compose a great part of Ingleborough, and other adjacent mountains in the district called Craven, in Yorkshire, generally dip at a moderate inclination towords the south-east; the lower beds rest on coarse slate, which has in reality the same inclination as the limestone, but as the under part of the slate is often concealed, the vertical partings are mistaken for strata seams. This limestone is described by Professor Playfair as resting on vertical beds of slate; and he draws several important conclusions respecting the elevation of the beds of slate, and its action on the superincumbent beds of limestone; whereas a more extended survey of the district would have shown him, that the slate rocks rest on other beds, which have the same inclination as the limestone above them, and that the slate and limestone are conformable.

The modes of stratification we have been considering are those of plane strata; but in many situations, particularly in the Alps and the Jura chain, the strata are curved and bent round the mountains, encircling them like a mantle. The ravines and escarpments, according to the position in which the sections have been made, present the most varied forms of stratification in the same mountain. In one part, the strata will seem to rise almost vertically; in another to be nearly horizontal; and in a third, to be deeply curved: and this will depend much on the relative position of the observer, whether he be placed on one side, or in face of the escarpment. Suppose a transverse section be made through a mountain in the direction *a b*, (Plate I, fig. 6,) it would show the true position of the arched strata; but if we suppose a section to be made only on the side *c d*, an observer would see the face or escarpment on that side, with the edges of the strata lying horizontally, and might describe them as horizontally stratified, were he to view no other part of the mountain. In some situations, the fracture made in the arched stratification is much broken, and we have on the side of the same mountain, the appearance both of horizontal and greatly inclined stratification. An instance of this occurs near the Lake of Bourget, in Savoy. Plate II, fig. 1, represents the appearance of strata on the side of a mountain, which has the arched stratification before described; but the outermost strata, instead of enfolding the whole mountain, only cover the southern side, and are broken off at the summit in a line nearly parallel with it, and their

edges present the appearance of horizontal strata, *a a a*. Lower down the mountain, part of the under strata have fallen off in a sloping direction, and their projecting edges present at a distance the appearance of highly inclined strata.* This may be further illustrated by taking a half cylinder, or, for want of that, a thick book, and opening it a little, place it with the edges upon the table, and the back uppermost; cover the book or half cylinder with a number of folds of paper of different colors,—these will represent arched strata. Cut across the outermost folds along the back, and take away the other half; the edges of the paper will represent those of the upper strata, and their position will appear to be horizontal. Cut away the corners of the under sheets a little behind each other, so that the edges of each colored sheet may be visible, and these will represent the appearance of highly inclined strata, and have frequently been mistaken for such. The young geologist may greatly facilitate the study of stratification, by laying colored planes of any sort and yielding substance over each other, and inclining them in various positions; then let him make sections in different directions with a knife, and also carve out hollows representing valleys, cutting through inclined strata at various angles with the line of dip and line of bearing: by this means he may gain a more correct idea of the varied phenomena of stratification, both in mountains and valleys, than the most elaborate descriptions can convey.

The appearance of contorted stratification in the calcareous mountains of the Alps, is frequently an optical illusion. Strata which have originally enfolded a mountain like the coats of an onion, have fallen off in curved lines, leaving waving edges overlapping each other, as represented Plate II, fig. 5. Suppose indented sections were made in the side of an onion, the edges of the different indented rinds would present similar contortions. Inequalities in the general curvature of the beds may have occasioned them to break off in this manner. The *Montagne de Tuille*, near Montmelian, in Savoy, of which a plate is given in the third volume of Saussure's *Voyages dans les Alpes*, offers an instance of this apparent contortion, which Saussure considers as almost inexplicable. I examined this mountain from various stations with much attention, and am convinced that the contortions are only illusory, and are not like the real contortions, which the lower beds of transition limestone, in this country, frequently present on a small scale. In certain situations in the Alps, however, the strata have evidently been raised by some violent convulsion, and have been bent by the resistance which they have

---

* In this section, the mountain is represented as cut through, to show the bending of the strata; but the edges of the strata *a a*, and of the strata below, were only visible, and it required much attention to discover their true position.

offered to the moving cause. Of this, a remarkable instance may be seen in the Baltenberg mountain, at the head of the lake of Brientz, of which I have given a description and drawing in the second volume of my Travels in the Tarentaise.

The strata of secondary rocks belonging to the same formation, frequently preserve nearly the same thickness for a considerable extent, and are arranged conformably over each other, except in situations where their regularity has been disturbed by rents or fractures. In these secondary conformable strata, the order in which they succeed each other indicates their relative ages; but this rule cannot be extended to all classes of rocks.

No inference can at first appear more legitimate than this: "The rock which supports another must be older than that which rests upon it, if their original position has not been changed." But this conclusion, when examined with attention, will fairly admit of doubt, with respect to those rocks which are crystalline like the primary. These were either formed by chemical affinity from a state of solution, or by crystallization from a state of fusion: if by the latter mode, all the different beds may have been arranged at the same time, and the upper and lower rocks may have a contemporaneous origin. If a mass of melted matter from a furnace cool slowly, the internal and external parts will vary both in their physical and chemical properties; but it cannot, on this account, be said, that the lower part is older than the upper. But strata deposited by water were evidently formed after the rocks on which they rest. Even were we to admit the subsequent fusion of granite, it existed in another form as a substratum of the upper rocks, as these must always have had a foundation. It has been before observed, that those rocks which contain different species of organic remains, separated by strata in which no such remains occur, must have been formed in succession over each other, and probably at very distant intervals of time. This inference appears conclusive, nor can it be invalidated by the crystalline arrangement and cleavage of some of those rocks.*

Rocks of the primary class frequently cover each other in an order, which, viewed on a grand scale, may be said to be conformable; but the different rocks in each class are generally of such vast and irregular thickness, that their order of succession is often not easy to trace; beside, some of these rocks pass by a change of structure into each other, and their line of junction or

---

* We have reason to believe that many rocks which present no indications of stratification, were originally arranged in regular strata. In some limestone rocks, where the stratification is extremely well defined by distinct partings, there occur spaces in which different strata are blended into one mass. These masses are called by the quarrymen, knobs, and are more hard and difficult to work than the stratified limestone, but are equally good in quality.

separation can seldom be observed. Viewed, however, as composing mountain chains, the more general arrangement is represented Plate III, fig. 1. Granite, or the foundation rock, *a;* gneiss, *b;* mica slate, *c;* common slate, (called clay slate,) *d d.* The transition series, *c c.* The lower strata with coal, F F. A bed of limestone, or any other rock, in a slate mountain, is represented, *x x:* in this position it is said to be *imbedded:* and if a number of these beds occur at different intervals, they are said to be subordinate. A bed of conglomerate, composed of boulders and fragments of the lower rocks, as at G, is frequently interposed between slate rocks and transition limestone.

The unconformable position of unstratified rocks is represented Plate III, fig. 2, where a mass of porphyry A, ranging from C to C, covers the rocks 1, 2, 3, without any conformity to the inclination or form of the lower beds. The lower beds are, however, cut through by veins of porphyry, which indicate that the porphyry had been erupted in a melted state through these veins, and poured over the surface of the lower rocks. A similar arrangement of porphyry, which occurs in Norway, will be described in Chapter X.

Basalt, either massive or columnar, frequently covers rocks in an unconformable position. See Plate III, fig. 2, B, *d* and *b.*

The superincumbent rocks in this situation are evidently of more recent origin than those which they cover; the lower must have been hard and unyielding when the upper were thrown upon them. If a thick stream of lava, as frequently happens, were to flow over a range of conformable rocks, filling up the cavities and inequalities of the surface, when it became hard by cooling, it would form a bed of superincumbent unconformable rock. Such instances are common in volcanic countries. Very extensive ranges of rocks and mountains occur in this position in various parts of the world, not only covering the primary, but the secondary rocks. These will hereafter be described under the name of porphyry, sienite, and basalt. They frequently assume the columnar structure, and sometimes form vast ranges of natural pillars; as at Staffa, one of the Hebrides, on the north coast of Ireland, in Iceland, Sicily, and many volcanic countries.

Having described the position of both stratified and unstratified unconformable rocks, it may be proper to state, that the latter rocks occur, covering both primary, transition, secondary, and tertiary strata: many of those which cover the secondary and tertiary, seem evidently to have been the products of subterranean fire; and even those which cover the primary and transition rocks, bear a close affinity to volcanic rocks. If we admit that our loftiest ranges of mountains were elevated by the expansive force of central fires, this power acting upon an extensive portion of the globe, might be ages in upheaving the incumbent surface,

which would continue to rise until vast fissures were made, through which the subterranean melted matter would be thrown over the mountains and plains then existing, and form the superincumbent rocks of basalt, porphyry, and sienite, that seem to be so nearly allied to volcanic products. While one part of the surface was rising, another part would sink, and form a new bed, into which the waters of the ocean would gradually retire.

According to Humboldt, the extraordinary eruptions by which new islands have been formed since the period of authentic history, have been preceded by a swelling of the softened crust of the globe. At Kamenoi, the new island made its appearance above the sea twenty six days before the smoke was visible. "Every thing indicates that the physical changes of which tradition has preserved the remembrance, exhibit but a feeble image of those gigantic catastrophes which have given mountains their present form, changed the position of the rocky strata, and buried sea shells on the summit of the higher Alps. It was undoubtedly in those remote times which preceded the existence of the human race, that the raised crust of the globe produced those domes of trappean porphyry, those hills of isolated basalt in vast elevated plains, those solid nuclei covered with the modern lavas of the Peak of Teneriffe, of Etna, and Cotopaxi."—*Humboldt.*

To these great catastrophes, and to vast inundations, and in some cases to submarine currents, must we ascribe many inequalities of the earth's surface, the fracture of strata, and the transport of the broken masses and fragments into distant countries. The formation of valleys constitutes an important subject of geological research: it will be reserved for a subsequent part of the volume; but it may be useful to state to the geological student, that all stratified mountains are only parts of extended strata, with which they were once united.

This will be more distinctly understood by consulting Plate IV, fig. 1, which is intended to represent the general rise of the strata from Sheffield in Yorkshire to Castleton in Derbyshire, intersected by the valley through which the river Derwent flows.

The town of Sheffield, fig. 1, is built over coal strata, which rise towards the west, and disappear in that direction about five miles from Sheffield (2.) Here the under rock makes its appearance (3,) which is a bed of coarse gritstone, more than one hundred and twenty yards in thickness, forming the summits of all the mountains as you advance to the vale of Derwent (4.) The grit-rock rests upon a thicker bed, of a different kind, chiefly composed of slaty sandstone, represented (5.) On the western side of the valley, the grit-rock (3) exists only as a cap or covering on Whin Hill, a lofty mountain, marked (6.) Two miles farther west the grit-rock disappears, and the slaty sandstone, which is the base of Whin Hill, forms the summit of the celebrated Mam

Tor, or the Shivering Mountain. The mountain limestone (7) here makes its appearance as the base of Mam Tor, and farther west the same limestone forms entire mountains. The difference observable in the rocks east and west of the Derwent, is owing to the general rise of the strata in the latter direction.

It is here obvious, that Whin Hill, though it appears an isolated mountain, is only a portion of the thick beds of gritstone, and slaty sandstone, on the other side of the valley: the cap of grit rock (6,) is called an outlier of the bed 3.

It deserves notice, that isolated caps, like that on the top of Whin Hill, fig. 6, often occur where we can trace no similar rocks in the vicinity: they are sometimes the only remaining relics of a stratum that has been destroyed, and removed by some of the great catastrophes that have changed the surface of the globe.

When valleys take the same direction as that of a range of mountains, they are called *longitudinal valleys;* when they cut through a range of mountains, they are called *transversal valleys:* in the latter case, the strata on each side of the valleys are generally the same.

The small valleys which open into a larger valley nearly at right angles to it are called *lateral valleys.* In some rare instances, a valley is formed by the bending of the strata, which make a trough, as represented Plate I, fig. 2, between A and B.

When considerable tracts of the upper strata are wanting, as between A, B, Plate I, fig. 2, it is supposed that the lower strata have been laid bare by some convulsion that has torn off and carried away the strata by which they were once covered: this constitutes what is called a denudation. Instances of such denudations are of frequent occurrence.

Mountains, except those formed by volcanos, are seldom isolated masses rising from a plain, but they form groups, or are ranged together in a certain direction, and compose long and lofty ridges, denominated mountain chains. Lower ranges of mountains, running in the same direction as the principal range, and separated by valleys of greater or less width, may be observed accompanying almost all very lofty mountain chains. This fact appears to indicate the operation of a powerful elevating force, acting in one direction along a certain line,* and decreasing in intensity as the distance from each side of this line increases; but this action does not appear to extend with equal force on both sides of the line, for the smaller chains parallel to the great chain are seldom so numerous on one side of it as on the other. The principal mountain chain, if very large, has its sides furrowed by small lateral valleys, and has not been unaptly compared to a back-bone or spine, with diverging ribs.

---

* This line is called the axis of elevation.

The shape of many countries and islands is evidently determined by the direction of the grand mountain chains that run through them.

The principal mountains in Europe and Asia, when viewed on a large scale, may be considered as forming a mountain chain composed of numerous mountain groups, and extending in an easterly direction from Cape Finisterre in Spain, to the most eastern extremity of Asia. Various parts of this chain receive different denominations in the different countries through which they pass. The Pyrenees, the Alps, Mount Taurus, Mount Caucasus, the Altaic, and the Himmaleh mountains, and the Yablonny mountains of Tartary, which extend nearly to Behring's Straits, may be regarded as forming together one immense mountain chain, and dividing the northern from the southern dry land, both in Europe and Asia.

In North and South America one unbroken chain of mountains runs in a northerly and southerly direction for eight thousand miles, near the western side of that vast continent, and, with some minor diverging chains, has evidently determined the general outline of both countries.

A remarkable similarity occurs in the position of the escarpments or steep sides of mountains in the same mountain range. Various opinions have been formed respecting the law which the position of the escarpments appears to follow, but I believe the rule I submitted to the attention of geologists in the first edition of this work, will be found to approximate to the truth.

Mountain chains or ranges present the steepest declivities on the sides nearest to the sea. This is remarkably the case in the long chain of the Alleghany mountains on the eastern side of America, which are steep towards the Atlantic. On the contrary, the Stony mountains, which run near the northwest coast, and the Andes, near the southern Pacific Ocean, are steepest on their western side. In ranges of mountains that form the boundaries of lakes or of extensive vales, through which large rivers flow, the mountains nearest to the rivers have the steepest declivities. The largest rivers have their origin from the sides of mountains which are most inclined to the horizon, and most remote from the sea.

The beds or strata, of very lofty mountains, are generally much inclined, and are sometimes nearly vertical. Among these highly inclined beds, we not unfrequently observe beds of limestone containing marine shells, which must have been originally deposited at the bottom of the ocean. In some instances we meet with vertical strata, containing rounded pebbles and water-worn fragments of other rocks; these must also have been originally deposited on a surface nearly horizontal: we are therefore certain, that the present vertical position of these strata is not their original one, and

we hence also learn, that all the strata associated with them in the same mountain, and having the same inclination, were raised together. We have further proof that, before the epoch when this great revolution was effected, all these beds were covered by the seas then existing, and it was under the ocean that the change of position took place.

No person who reflects on the appearances presented in a mountianous district can believe that the broken and elevated beds, the peaked summits, the impending cliffs, and the immense fragments of rock scattered in the valleys and adjacent countries, were originally created and placed as we now observe them.

The traveller who, in crossing an extended desert, should meet with the remains of some unknown temple, could not for a moment doubt that the broken and prostrate columns, the mutilated arches, the scattered capitals and inscriptions, had been removed by some devastating cause from their original position; nor is the proof less certain, that the rocky pavement of our globe has been broken, and its parts, which were once united, widely separated from each other. Some of the phenomena we observe in mountains were produced by the disturbing force which first elevated them; others have been subsequently effected either by vast inundations, or by torrents that have torn away considerable portions of the softer beds, or by the more gradual decomposition and disintegration produced by atmospheric influence; by the latter cause, the lofty and exposed peaks and escarpments of rocks are constantly wearing down.

During the two summers I passed in the Alps, I was much struck with the circumstance, that all the great openings or passages over these mountains, called *Cols*, were made by excavations in beds of soft slate; and the fact I think admits of an easy explanation, but I do not know that it has been before remarked by geologists.

If we suppose a portion of the Alps to be represented, Plate II, fig. 2, the dotted lines above the present surface will mark the supposed original prolongation of the different beds, at the period when they were raised. As the ocean, from whence these beds were raised, must have been agitated with inconceivable violence, the retiring waters would scoop out deep excavations in the softer beds of schist, and also tear off many of the vertical plates of the hardest rocks, and form the rudiments of these pyramidal peaks and aiguilles, which rise like the spires of a Gothic cathedral. Mountain torrents, caused by thunder-storms or the sudden melting of alpine snow, may have subsequently torn away large portions both of the harder and softer beds: the disintegration of the granitic aiguilles which are exposed to the influence of atmospheric agency is daily taking place, and their ruins are every day falling on the surface of the glaciers, and are carried down into the valleys:

their peculiar forms are derived from their laminated structure, which disposes them to split in a vertical direction.*

It is important to observe, that different groups and ranges of mountains have been elevated at different and remote epochs, and the birth of different parts of the same continent was not coeval: the more lofty parts constituted separate islands, before the whole surface emerged from the ocean. Satisfactory evidence of this will be adduced in a subsequent part of this work: it is sufficient to the present purpose to state, that the ocean has covered all that is now dry land, but not at the same epoch.

* Plate II, fig. 2, represents the general position of the beds near the Col de Balme and Mont Blanc; *a a a*, alternating beds of sandstone and limestone; *b b*, elevated beds of puddingstone, containing rounded stones and fragments of the lower rocks; *c c*, soft slate, in which a passage or col is formed; *d d d*, vertical granitic beds rising in pyramidal forms, called Aiguilles or Needles.

CHAPTER V.

ON ROCKS DENOMINATED PRIMARY, AND THE CHANGES TO WHICH THEY HAVE BEEN SUBJECTED.

The Origin of Rocks called Primary believed by many Geologists to be igneous.—A Classification founded on this View.—A Classification independent of Theory.—Constituent Minerals of Granite.—Varieties of Granite.—Structure and Appearance of Granitic Mountains.—Mont Blanc, and the Aiguille in its Vicinity.—Localities of Granite.—Granite Veins.—Passage of Granite into Porphyry and Sienite.—Minerals found in Granite.—On Granite as the Foundation Rock on which other Rocks are laid.—The relative Antiquity of different Granitic Mountain Ranges.—Granite pierced through by Porphyry and Currents of Lava.—Granite sometimes protruded among the upper Strata.

In describing the different classes of rock, we may either commence with the lowest or most ancient, or with the uppermost or most recent; but I am persuaded that the student will find it most convenient to begin with the lowest, and proceed in an ascending series to the uppermost. The rocks called primary have distinctly marked mineral characters, and contain few, if any, organic remains. As the student proceeds, he may trace the first indications of organic existence, and in ascending to the upper rocks, he will observe the gradual increase of genera and species that have left their remains in the different beds; in some cases indicating great changes in the condition of parts of the globe, as from sea to land, or from salt water to fresh, or from deep to shallow seas. If the student begin with the more recent or uppermost strata, he will find them difficult to recognize by fixed mineral characters, and he will be confused by the variety of organic species presented to his notice, but from which he can derive little instruction, until he be able to compare them with the fossil remains in the lower strata. In the geological description of a particular country or district, it may often be more convenient to commence with the beds nearest the surface, and proceed in a descending series; but then the reader is supposed to be already acquainted with the science.

If any rocks can with propriety be denominated primary or primitive, they are those which are most widely spread over the globe in the lowest relative situation, and which contain no remains of organic existence. Primary rocks are supposed by geologists to constitute the foundation on which rocks of all the other classes are laid; and if we take an enlarged view of the structure of the globe, we may admit this to be the fact; but the admission requires certain limitations. The same causes that

have produced granite and the other primary rocks in immense masses below all other rocks, have in some situations reproduced them in smaller masses, covering rocks belonging to the transition or secondary classes.

Granite, for instance, which has been regarded as the most ancient of all known rocks, has been sometimes found covering secondary rocks, and sometimes obtruded between them. Facts of this kind are rare, and can only be explained by admitting that granite, like volcanic rocks, has once been in a state of fusion, and was protruded in this state through the upper rocks. Similar facts are observed with respect to other primary rocks, which are believed to be of igneous formation.

Indeed, if the science were sufficiently advanced to enable us to pronounce with absolute certainty on the agents by which rocks were formed, a more intelligible arrangement might be substituted, than one founded on their relative ages; it might be comprised in three great divisions:—

Class I. *Rocks of igneous Formation.*
Class II. *Rocks of Aqueous Formation.*
Class III. *Conglomerates, and Mechanical Formations.*

These would admit of distinct subdivisions:—

Class I. *a.* Rocks that have been fused and consolidated, without ever having flowed as lavas.
b. Rocks that have been fused and protruded through the solid covering of the globe.
c. Rocks that have been greatly modified by heat, but which were originally aqueous depositions.
Class II. *a.* Marine formations.
b. Fresh-water formations.
Class III. *a.* Ancient conglomerates.
b. Recent conglomerates.

Each of these divisions would comprise rocks of different relative ages: that of rocks of the first class would be determined by their position; those of the second and third classes, by their order of succession, and the organic remains in each.*

* Such an arrangement might be objected to, as resting too much on theory; and the fate of the Wernerian system ought to caution us against founding systems of classification on theoretical views respecting the formation of rocks. The following rocks, according to the evidence at present obtained, might be referred to the different divisions of the first class; and it may be useful to bear this in mind, without yielding implicit assent to the theory that they are all igneous formations; yet it must be allowed, that such a mode of formation will satisfactorily account for many positions in which these rocks occur, that appear inexplicable by any other theory.

I shall now proceed to describe the rocks denominated primary, without any reference to theory, and shall propose an arrangement of them that will, I trust, be found conformable to the present state of the science.

Primary rocks are chiefly composed of the hard minerals, quartz, felspar, and hornblende ; the minerals, mica and talc, are disseminated in smaller proportions, and limestone and serpentine occur in beds or masses, but less frequently than the above named minerals. If we refer the slate rocks to the transition class, the few simple minerals here enumerated constitute nearly the whole of the mountains denominated primary.

The structure of primary rocks is crystalline ; they form the central parts of the most elevated mountain chains, and they occur also at the lowest depths that have yet been explored, and are hence believed to be the most ancient of rock formations.

Werner has enumerated fourteen primary rocks ; but as some of these have only been found hitherto in one place, it appears improper to consider them as distinct orders, unless we arrange every variety of rock in the same manner, and increase the number of orders indefinitely.

The following arrangement of primary rocks includes only three principal rocks as primary—granite, gneiss, and mica slate, which are nearly allied to granite, and form an incrustation over it: these never contain organic remains, and they have rarely been observed lying over other rocks in which such remains are found. It comprises also the rocks which are sometimes found imbedded in granite, gneiss, and mica slate, and are regarded as subordinate formations.

Class I.

Principal Rocks denominated Primary.

1. Granite, comprising all the varieties of this rock, and small-grained granite passing into porphyry, the Eurite of the French geologists, primitive porphyry of the Germans.
2. Gneiss, or slaty granite.
3. Mica slate.

Subordinate Rocks which occur among Primary.

Hornblende rock.
Serpentine.
Crystalline limestone.
Quartz rock.

Supposed Igneous Rocks.—All varieties of granite, gneiss, and mica slate ; all varieties of porphyry and felspar rocks ; all varieties of hornblende rocks and serpentine ; all basaltic or trap rocks ; all ancient and recent lavas.

In subdivision *c*, slate rocks, clay-slate, and crystalline limestone, imbedded in igneous rocks.

Some of these subordinate rocks occur also among rocks of the transition class.

The three principal rocks of the primary class,—granite, gneiss, and mica slate,—might, with propriety, be regarded as belonging to one formation. They are essentially composed of the same minerals, varying in different proportions, and are rather modes of the same rock than different species. They pass by gradation into each other, as one or other of their constituent minerals become more or less abundant; they alternate with each other in various situations, and may be regarded as contemporaneous. It may, however, for the convenience of description, be proper to treat of each separately.

Rocks of the first Class.

Granite is considered as the foundation rock, on which slate rocks and all secondary rocks are laid. From its great relative depth, granite is not frequently met with, except in alpine situations, where it appears to have been forced through the more superficial covering of the globe. Where granite rises above the surface, the beds of other rocks in the same district generally rise towards it, and their angles of elevation increase as they approach nearer to it.* Granite is composed of the three minerals described in the third chapter,—quartz, felspar, and mica,—which are more or less perfectly crystallized, and closely united together.

The three minerals of which granite is composed, vary much in their proportions in different granitic rocks, and often in specimens from the same rock the crystals are large, or small, or equally intermixed, in one part, and in another part, quartz or felspar greatly predominates. Some granites are composed of small grains, and have large crystals of felspar interspersed; these are denominated porphyritic granites. Stones of this kind are common in the foot-pavements of London.†

Felspar constitutes by far the largest part of granite: the more common colors are white and red; it is sometimes in a soft or decomposing state, and appears earthy. In some granites, the crystals of felspar are distinctly formed. Quartz generally occurs in small irregular shaped grains, which have a vitreous lustre.

---

* Some writers derive the name from *geranites*, a word used by Pliny to denote a particular kind of stone; others, with more probability, suppose that the name originated from its granular structure, or the grains of which it is composed.

† Specimens of Cornish and Scotch granites are not difficult to procure in London, as they are commonly used for paving-stones. In the former the felspar is white; the mica appears like glistening scales which have a tarnished semi-metallic lustre. The quartz has a vitreous appearance, and is of a light grey color. In Scotch granite the felspar has more commonly a reddish-brown color. The mica is not unfrequently black and splendent, and may be divided into thin scales by the point of a penknife: this distinguishes it from hornblende, which is sometimes intermixed with this granite.

The mica in granite occurs most commonly in small shining scales, which are generally either black, or whitish and silvery. It sometimes occurs in large hexagonal plates; but this is more commonly the case in the granite that forms veins in granitic mountains; such veins, with large plates of mica, are frequent near Aberdeen, in Scotland. Mica readily separates or divides into thin transparent laminæ; and where the plates are very large, as in the Siberian granite, it is used instead of glass for windows. This variety is improperly called Muscovy talc. Talc resembles mica, but is much softer. When the grains of felspar and other minerals are very minute in granite, it can scarcely be distinguished from sandstone.

Beside the three minerals, quartz, felspar, and mica, which were formerly considered as the essential constituent parts of all true granite, whoever has attentively examined various granitic districts, must have frequently observed, that other minerals occupy the place of mica, either in part or entirely. Thus near the summit of Mont Blanc, the granite is composed of felspar, quartz, and talc or chlorite, the latter mineral supplying the place of mica. To this variety of granite the name of protogine has improperly been given, whereas *talcy* or *chloritic granite* would at once convey a distinct idea of its nature. In some instances, hornblende supplies the place of mica, or is intermixed with it. To this rock the name of sienite was given, because a granitic rock of this kind from Sienna, in Upper Egypt, was much used by the ancients for obelisks.

The following varieties of granite are often associated in the same granitic mountains, and may be regarded as contemporaneous with it, being essentially the same rock, accidentally modified by an admixture with other simple minerals.

Common Granite.—Composed of quartz, felspar, and mica. The felspar, white or red.

Porphyritic Granite, in which large crystals of felspar occur in a small-grained granite. The granite near Shap, in Westmoreland, offers an excellent type of this.

Sienite or *Sienitic Granite*, in which hornblende, either wholly or in part, supplies the place of mica. The granite of Malvern, and the Charnwood Forest hills afford specimens of this granite.

Talcy, or *Chloritic Granite.*—Quartz, felspar, and talc or chlorite. Many of the granitic mountains in Savoy are composed of this granite; and loose blocks of it are scattered over the valleys and on the sides and summits of the calcareous mountains, in the countries to the north and northwest of the Alps. This granite is by some writers called protogine.

Felspathic Granite, in which the felspar is the principal ingredient, and the quartz, and particularly the mica, very rare; larger crystals of felspar occur in it. It is frequently nearly white. To

this variety Werner has given the name of white stone, and the French, eurite. It occurs in beds in common granite in Cornwall. In its most compact form, it becomes a porphyry, and is closely allied to volcanic rocks in Auvergne. Indeed the common granite of Auvergne I observed to be chiefly composed of felspar and quartz without mica; in some parts, the mica was replaced by the mineral called pinite.

Granite occurs in masses of vast thickness, which are commonly divided by fissures into blocks, that approach to rhomboidal or pretty regular polyhedral forms. Sometimes a columnar structure may be observed in granitic mountains; in other instances, where the quantity of mica is considerable, granite divides into parallel layers or plates, that have been mistaken for strata. Granite is occasionally found in globular masses, which are composed of concentric spherical layers, separated by granite of a less compact kind, and enclosing a hard or central nucleus. These globular masses are often three or four yards or more in diameter, and are either detached or imbedded in granite of a softer kind; this structure is not peculiar to granite.

The aspect of granitic mountains is extremely various: where the beds are nearly horizontal, or where the granite is soft and disintegrating, the summits are rounded, heavy, and unpicturesque. Where hard and soft granite are intermixed in the same mountain, the softer granite is disintegrated and falls away, and the harder blocks remain piled in confusion on each other, like an immense mass of ruins. Where the granite is hard, and the beds are nearly vertical, and have a laminar structure, it forms lofty pyramidal peaks or aiguilles, that rise in enormous spires; such are the aiguilles in the vicinity of Mont Blanc, which are far more interesting, both to the picturesque traveller or the geologist, than Mont Blanc itself. The Aiguille de Dru is, perhaps, the most remarkable granitic mountain at present known. The upper part, or spire, rises above its base nearly to a point, in one solid shaft, more than four thousand feet; the summit is eleven thousand feet above the level of the sea.*

It has been observed in so many situations, that it may perhaps be regarded as a general law,—wherever granite rises high above the surface of the earth, the strata of limestone or other rocks in its vicinity rise towards it. Numerous instances of this occur in the Swiss Alps. In the higher part of the valley of Lauterbrunn, in the Canton of Berne, I have seen a bed of limestone in immediate junction with granite, in a perfectly vertical position, like a wall built up against it; but both rocks were cemented together without any perceptible line of parting. The limestone was ex-

* A short description of this mountain, with a plate, is given in the second volume of "Travels" by the author.

tremely hard, but the parts in immediate contact with the granite did not differ in appearance from the other parts of the bed.

In many of the highest mountains in the northern or Swiss Alps, granite is only seen near their bases; the summits are composed of immense beds of limestone, and secondary stratified rocks. In the southern chain, or the Savoy Alps, the highest summits are granite; indeed, the highest known point at which granite has been observed in any part of the world is Mont Blanc in Savoy, the loftiest mountain in Europe, rising fifteen thousand six hundred and eighty feet above the level of the sea, or nearly five times higher than any mountain in England or Wales. It was first ascended by Dr. Pacard in 1786, and afterwards by Saussure, who has published a very interesting account of his ascent. Several persons have since ascended this mountain, but Saussure is the only traveller who has given us any information respecting its structure. I shall therefore insert a brief account of his observations; they are highly interesting. He set out from the priory of Chamouni, from whence the distance to the summit of the mountain, in a direct line, is not more than two French leagues and a quarter: but owing to the difficulty of the ascent, it requires eighteen hours' continued labor, exclusively of the time necessary for repose and refreshment. The first day's journey was comparatively easy, the route being over soil covered with vegetation, or bare rocks. The ascent on the second day was over snow and ice, and more difficult: at four o'clock in the afternoon of the same day, Saussure and his attendants pitched their tent on the second of the three great plains of snow which they had to traverse. Here they passed the night, fourteen hundred and fifty-five toises (or three thousand one hundred yards) above the level of the sea, and ninety toises higher than the Peak of Teneriffe. The barometer stood at seventeen inches. The next morning they proceeded with much difficulty and fatigue, arising principally from the extreme rarity of the atmosphere, which affected their respiration. The upper parts of Mont Blanc are above the limits of perpetual snow, and it is only on the sides of the nearly perpendicular peaks and escarpments that the bare rock is visible. They gained the summit by eleven o'clock, A. M. "From this elevated observatory," says Saussure, "I could take in at one view, without changing my place, the whole of the grand phenomenon of these mountains; namely, the position and arrangement of the beds of which they are composed. Wherever I turned my eyes, the beds of rock in the chains of secondary mountains, and even in the primary mountains of the second order, rise toward Mont Blanc and the lofty summits in its neighborhood: the escarpments of these beds of rock were all facing Mont Blanc, but beyond these chains were others whose escarpments were turned in a contrary direction. Notwithstand-

ing the irregularity in the forms and distribution of the great masses that surround Mont Blanc, and those which constitute the mountain itself, I could trace some features of resemblance not less certain than important. All the masses which I could see were composed of vertical plates, (*feuillets*,) and the greater part of these plates were ranged in the same direction, from northeast to southwest. I had particular pleasure in observing the same structure in the lofty peak of granite called the *Col du Midi*, which I had formerly endeavored, but in vain, to approach, being prevented by inaccessible walls of granite. After the second day's ascent, this lofty pinnacle was beneath me; and I fully convinced myself that it is entirely composed of magnificent plates (*lames*) of granité, perpendicular to the horizon, and ranging from east to west. I had formerly been induced to believe that these plates were folded round the peak, like the leaves of an artichoke, but this was an optical illusion when seen imperfectly from below: here, where the eye could as it were dart down into the interior structure of the mountain, the plates of rock appeared regularly parallel in a direct line. I was also," says Saussure, "particularly desirous of ascertaining whether the vertical beds were composed of the same substances at their summits as at their bases, where I had so frequently inspected them; and I am perfectly satisfied, from actual examination, that they preserve the same nature through their whole extent, and are the same at the summit as below."*—*Voyages dans les Alpes*, tom. iv.

The inference drawn by Saussure, respecting the vertical position of the beds of granite that compose a principal part of Mont Blanc and the adjoining mountains, is, that they were originally horizontal, and have been subsequently elevated by some tremendous convulsion of nature. The summit of Mont Blanc, he says, must at one time have been more than two leagues under the surface. To the same convulsion he also attributes the position of the escarpments or steep sides of the rocks which face Mont Blanc for a considerable extent, and then turn from it in an opposite direction. This would be the case had the surface of the globe been broken and elevated in the manner he supposes. There is a circumstance stated by Saussure, which tends strongly to confirm, if not absolutely to prove, the truth of his hypothesis. Some of the vertical beds of rock adjacent to the granite, contain round pebbles, boulders, and water-worn pieces of the lower rocks.

---

* The extreme fatigue and exhaustion which Saussure experienced during the ascent of Mont Blanc, is supposed to have abridged the life of this active and intelligent philosopher. It may amuse the reader to be told, that Saussure during his excursions in the Alps, wore a full-dressed scarlet coat and gold-laced hat. He informs us, that when he was seated on Mont Breven, the lace of his hat attracted the electric fluid from a passing cloud, and occasioned a hissing sound. *Tempora mutantur, et nos*, &c.

See observations on these beds, Chap. IV. It is impossible to conceive that those rounded fragments could have been placed in a vertical position; for, if they be really pebbles and boulders, the beds on which they occur must originally have been nearly horizontal. Now as these beds are at present placed between others which are also vertical, and in the same range, it follows, that the whole have been overturned and thrown up, at a period subsequent to their formation.*

The Himmaleh Mountains in the centre of Asia, rise ten thousand feet higher than any mountains in the Alps, but where their summits are uncovered by snow, they are believed to be composed of secondary strata.

Many of the mountains in the extensive range of the Andés in South America also rise much higher than Mont Blanc; but granite has not been found there in a greater elevation than eleven thousand five hundred feet, an elevation exceeded by many of the granite mountains in Europe. The range of the Andés is the seat of active volcanic fires, which appear to have covered the primary mountains with an immense mass of matter, ejected by ancient and recent eruptions. In Mexico and New Spain also, the granite appears to be nearly covered by basalt, porphyry, and lava, ejected from the numerous volcanoes which now exist, or have existed, in those countries.

To this accumulation of volcanic matter the mountains in South America owe their superior elevation. Chimborasso and Cayambo are nearly the highest mountains in the Andés,—the former rises twenty-one thousand four hundred and forty feet,—but their summits are vast cones, composed of volcanic productions covered with snow. Chimborasso is one mile and one hundred and sixty yards higher than Mont Blanc. The general arrangement of the Andés consists, according to Humboldt, of granite, gneiss, mica, and clay slate, as in the Alps; but on these are frequently laid porphyry and basalt, "arranged in the form of regular and immense columns, which strike the eye of the traveller like the ruins of enormous castles lifted into the sky."

In the eastern parts of the United States, and in Canada, granite is seen near the surface uncovered by other rocks, and does not rise to any great elevation. The constant occurrence of granite at a lower level in America than in Europe, is a remarkable geological fact. In Europe, the central part of the principal mountain ranges are granite; as in Scandinavia, the Alps, the Pyrenees, and the Carpathian mountains. In Asia, granite forms a considerable part of the Uralian and Altaic range of mountains, and it appears to compose the principal mountains that have been examined in Africa.

* Saussure says expressly, that the boulders in the rocks near Mont Blanc are precisely similar to the boulders on the shores of the lake of Geneva.

The parts of England and Wales where granite and granitic rocks occur are Cornwall, Devonshire, North Wales, Anglesea, the Malvern Hills in Worcestershire, Charnwood Forest in Leicestershire, and in Cumberland and Westmoreland. Granite rises near the bottom of Skiddaw in Cumberland. The granite near Shap, in Westmoreland, is porphyritic, containing large crystals of red felspar. There are rolled masses of granite on the banks of Ulswater, resembling the granite of some parts of Cornwall, and of the Wicklow Mountains, in Ireland, but more highly crystalline than the latter. The felspar is in large white and reddish-white crystals. The mica is a blackish-green, and on the outer parts decomposed. I am inclined to believe that the same formation of granite, which just makes its appearance on the western side of England and Wales, is continued under the Irish Channel; or, if broken there, it rises again in the Isle of Man, and in the counties of Dublin and Wicklow in Ireland. Blocks of granite are found in the beds of some of the rivers in the northwest part of Yorkshire, and in clay pits in Lancashire and Cheshire, at a great distance from any granite mountains. Most of the granitic rocks on Charnwood Forest are of that kind denominated sienite.* Among the English localities of granite, I have recently ascertained, that both granite and imperfect gneiss rise to the surface near Bedworth, in Warwickshire, evidently a continuation of the Charnwood granite.

Granite sometimes forms veins shooting up into the superincumbent rocks. This is a fact of some geological importance, as it seems to indicate, either that the granite has been in a state of fusion, the heat of which has softened and rent the upper rocks, and forced up the granite in a melted state into these fissures; or else that the granite and the rocks resting immediately upon it were both in a fluid state at the same time, and are contemporaneous. A remarkable instance of granitic veins in argillaceous schistus at Mousehole, in Cornwall, is described in Dr. Thomson's Annals of Philosophy, May, 1814. "The schistus is of a greyish color, rather hard, but breaks in large fragments in the direction of the strata. The granite is of a fine grain, and the feldspar is of a light flesh color, and contains but a small portion of mica. At the junction, numerous veins of granite may be traced from the rock of granite into the schist. Some of these veins may be observed upwards of fifty yards, till they are lost in the sea, and in point of size, vary from a foot and a half to less

---

* According to Brongniart, granite, sienite, and porphyry, are frequently observed graduating into each other in some parts of France; and he forms this conclusion:—En étudiant les granites d'un grand nombre de pays pour tâcher de distinguer clairement les anciens granites des nouveaux, on trouve presque peu de pays granitiques, qu'on puisse rapporter avec certitude à cette ancienne et primitive formation des granites."—*Journal des Mines, Mars*, 1814.

than an inch. It may deserve notice, that, as the felspar is of a flesh color, it is impossible for any observer to consider them as quartz veins: one of these large veins is dislocated, and heaved several feet by a cross course. Quartz, and fragments of schistus having the appearance of veins, are found in the granite veins. At one place there is a very curious and satisfactory phenomenon. One of these veins of granite, after proceeding vertically some distance, suddenly forms an angle, and continues in a direction nearly horizontal for several feet, with a schistus both above and below it. This appearance most completely destroys one of the theories suggested for the explanation of similar veins at St. Michael's Mount, viz. that a ridge of projecting granite had been left, and schistus deposited afterwards on its sides."

In 1816 I visited the place, which is close by the sea-side, at low water, and observed some appearances which I believe have not hitherto been noticed. The junction of the granite rock and the schist may be distinctly seen: they form together a sloping beach uncovered by any fragments: the line of junction is waving from the coast into the sea, as represented Plate II, fig. 3; G, the granite; S, the schist.

It is truly worthy of notice, that the veins of granite may be distinctly seen penetrating both the schist and the granite; for the granite in the veins is finer grained than the granite rock, and may as easily be distinguished in the granite as in the schist. The granite rock itself is smaller grained near the line of junction of the two rocks, than it is a little distance from it, where it contains large white crystals of felspar in a smaller grained reddish granite. What is further remarkable, the largest granite vein, in passing into the schist, cuts through a vein of quartz thicker than itself; and a few yards nearer the sea, a small quartz vein cuts through the same granite vein: see Plate II, fig. 3. What is called the schist or killas in Cornwall, in the places where I have observed it in immediate junction with granite, is highly indurated and of a dark color, and appears to have been changed by the junction: it has no appearance of slate;—indeed the diminished size of the grains of granite, as the latter approaches the killas at Mousehole, would indicate that the two rocks were passing into each other. Perhaps the best designation of the killas rock on this situation is, that of a minutely grained and highly indurated gneiss, that had lost its schistose character.*

Granite veins of large size traverse rocks of small grained granite and gneiss in the vicinity of Aberdeen: in these veins both the felspar and mica occur in crystalline plates and laminæ of considerable magnitude, accompanied with tourmaline. At Glentilt

* Some observations on the geological inferences, which may be drawn from these granite veins, will be found at the end of the present Chapter.

in Scotland, a singular intermixture of granite in veins and amorphous masses, occurs with slate and limestone, and has been described by Dr. MacCulloch in the Geological Transactions, vol. i, page 145. It seems impossible to conceive how masses of granite could be intermixed with, or imbedded in limestone, without admitting that the two substances have been both in a fluid or semi-fluid state at the same time; and we are not acquainted with any cause which could effect a simultaneous fusion of both rocks, except heat combined with pressure.

Some geologists describe the granite under gneiss, and the granite over gneiss as different formations; but as gneiss is itself a schistose granite, it would be more correct to state, that the massive and schistose granite sometimes occur alternating with each other. When the mica becomes abundant, the granite passes to the state of gneiss; when the felspar and quartz predominate, it becomes again massive or common granite.

What has been said respecting the alternation of gneiss and granite, will apply to the alternation of granite and mica slate. In the latter, the felspar is wanting; but if it reappear, it becomes either granite or gneiss. Mica slate also passes by such insensible gradations into slate, that the occasional occurrence of granite in some ancient slate rocks, may admit of a similar explanation.

There is a particular form of granite, in which the constituent parts are so minute and so intimately mixed, that it appears very minutely granular or even compact: to this variety the French geologists have given the name of *Eurite;* it has generally been described by English geologists as *Compact felspar*, into which it passes by insensible gradations. This rock frequently contains imbedded crystals of felspar, and forms what has been denominated felspar porphyry. In Cornwall it occurs in beds in common granite; but instead of being regarded as a different rock, it may be more properly classed by the geologist with granite, being only a variety in which felspar greatly predominates. This rock occurs also in an unconformable position, and is generally described as porphyry, and appears to form a connecting link between common granite and the compact varieties of volcanic porphyry, with a base of felspar called by the French *Trachyte.*

Sienitic granite, in which the mica is partly or entirely replaced by hornblende, in some situations occurs with common granite in the same bed, and therefore must be regarded as a variety of granite. Instances of this change from granite to sienite in the same rock, I have frequently observed in the granite of Charnwood Forest. The same change may also be noticed in the granite of the Malvern Hills. That able and accurate observer, Dr. Mac Culloch, maintains the identity of granite and sienite, from their frequent passage into each other in the same rocks in Scotland. When the hornblende becomes abundant, and is closely inter-

mixed with felspar, it forms a dark finely granular rock, which has been denominated trap or greenstone: it nearly resembles basalt. In the Charnwood Forest hills, and at Shap in Westmoreland, well defined granite may be seen passing into a dark colored trap rock nearly compact. I have even broken off hand specimens in which one part was granite and the other trap, and the passage from one to the other might be distinctly observed.

The crystallized earthy minerals which occur most frequently in granite, are schorl or tourmaline, and pinite, a mineral nearly allied to mica,—the emerald, corindon, axinite, and topaz, are also found occasionally in granite. Sometimes the tourmaline is so abundantly disseminated, as to form a constituent part of the rock.

Common granite, or massive granite, contains few beds of any other rock, nor is it rich in metallic ores. Tin ore, however, chiefly occurs in granite, either in veins accompanying quartz, or disseminated through the rock at a distance from the veins. Ores of other metals, as copper, iron, wolfram, bismuth, and silver, are also occasionally found in granite.

Granite supplies durable materials for architecture, but it varies much in hardness, and care is required in its selection. I was told, when in Cornwall, that granite got from a considerable depth in the quarry is so soft when it is first raised, that it can be easily sawed into blocks, but it soon acquires great hardness by exposure to the air. In the mountains of Auvergne, the granite is extremely soft, and the felspar appears earthy; this is probably the original state of the stone. I believe it is the soft earthy granite from this district, which supplies the kaolin used in the porcelain manufacture at Sevres. Mons. Brongniart, who obligingly accompanied me through the works, showed me a specimen of their best kaolin: it contained crystals of pinite. I had recently arrived from Auvergne, and I thought I recognized its locality.

Granite is regarded as the foundation rock on which all other rock formations rest, and has hence been called the most ancient formation; but if the age of a rock is to be dated from the period in which it became consolidated, the inference respecting its relative antiquity would not be conclusive. According to the Huttonian theory, granite is made of the melted crust of a former world, and the fusion may have taken place after this ancient crust was covered with the upper rocks; but, admitting that it has been fused under pressure, the matter that now constitutes granite must have existed in some mode or other, and have served as the foundation for the rocks that are upon it. If we date the age of granite from the period of the elevation of granite mountains, we must admit that some granite mountains are comparatively recent, for they have been elevated since the deposition of the secondary strata. I have shown this to be the

case with the granite of the Bernese and Savoy Alps, in my Travels in the Tarentaise, &c., published in 1823. In the third edition of the present work in 1828, I have also shown, by a description and sections, that the elevation of the granite of Savoy is more recent than that of the central part of England. M. Elie de Beaumont has since adopted the same views, and has extended them to other mountain ranges. Professor Sedgwick and Mr. Murchison have further proved, that a great part of the Tyrolean and Bavarian Alps was elevated since the deposition of tertiary strata; for these strata are lifted up with them, to the height of several thousand feet.

Here, however, we must also admit, that the material which formed granite is more ancient than the strata that rest upon it.

Whether granite ever formed at one time the stony pavement of the whole globe, or whether it was elevated in a solid state *bodily*, or whether different parts of the surface were fused at different epochs, are legitimate objects of geological inquiry, and may perhaps admit of a satisfactory solution by extended series of observations. In whatever state granite forms, or has formed, the ancient crust of the globe, it has been since pierced through by ancient and recent igneous rocks. Thus porphyry cuts through, and in some parts covers granite, on the west side of Scotland, from Inverary to Ben Nevis.

Volcanic rocks and streams of lava, of a recent geological epoch, pierce through, and have poured over the granite of Auvergne, and a large part of central France. Some of the currents of lava appear as fresh as the recent currents from Etna or Vesuvius. In other parts of Auvergne, the granite appears to have been acted upon by subterranean fire *in situ*, and in some mountains, as in the Puy de Chopine near Riom, granite and volcanic rocks are intermixed, one part being true granite, and the other volcanic porphyry (trachyte.)*

These volcanoes have long been dormant; and the only remaining proofs of the existence of subterranean fires under that district, are the hot springs that rise in the vicinity of the ancient volcanoes. According to Humboldt, in the Canary Islands, as well as in the Andes of Quito, in Greece, and various parts of the world, subterranean fires have pierced through the primary rocks; and he adduces the great number of warm springs which he has seen issuing from granite, gneiss, and mica slate, as a proof of this opinion. Indeed, in the Andes, numerous volcanoes are in present activity, from Cape Horn to Mexico; and it is probable that those mountains owe their elevation to subterranean fire; for we have a recent instance of the mighty power

---

* See "Travels in the Tarentaise and Auvergne," Vol. II, p. 367.

of this agent to upheave the crust of the globe. During the earthquake in Chili, in November, 1822, the whole line of coast, running north and south from Valparaiso, to the distance of one hundred miles, was raised above its former level; the bottom of the sea was laid dry, and shells were discovered sticking to the rocks, some of which were not before known in those seas. It is stated by an observer, that the whole country, from the coast to the feet of the Andes, and even far out to sea, was permanently raised by the earthquake; the greatest rise was about two miles from the shore. The granite, which forms the foundation rock, was rent in parallel fissures. The earthquake is estimated to have extended over an area of one hundred thousand miles. The average rise of the land upon the coast was from two to five feet; at the distance of a mile from the shore inland, the elevation was seven feet.

During my residence in Savoy and Switzerland, in the years 1820, 1821, and 1822, I was desirous to ascertain whether there were any vestiges of the action of subterranean fires in the Alps. In the part of the great southern chain, extending from near the source of the Rhone to the Little St. Bernard, there do not occur in the numerous situations which I examined, or from which I have seen specimens, any minerals of a volcanic character, with the doubtful exception of some rocks in the valley of Saas and in the Valorsine.

Though I could observe no indications of volcanic fire in the rocks themselves, I was greatly surprised with a circumstance that, as far as I know, had escaped the attention of geologists. Along the whole line of Alps before mentioned, which extends for one hundred and twenty miles, numerous hot springs are gushing out at the feet of the primary mountains, near the junction of the lowest secondary limestone, with schistose rocks passing into mica and talcous slate. It was known that a few thermal waters existed in the Valois and in Savoy, but they were regarded as isolated phenomena, and their geological position had not been attended to. Since Saussure visited the Alps, thermal waters have been discovered in various situations; and since I left Savoy, another considerable warm spring has been opened in the vicinity of the village of Chamouni, near the foot of a glacier.

There is also further reason to believe, that thermal waters would be found in all the deep valleys of the Alps, near the junction of the primary and secondary rocks, were they not covered by *éboulements* under heaps of loose stones, (as was the case with the warm baths in the valley of Bagnes in the Bas Valois,) or were not the temperature of the warm springs reduced by admixture with torrents from the glaciers.

In Vol. I, ch. 8, of my "Travels in Savoy," I have described the geological position of nine of the principal known thermal waters of the Alps; their temperature varies from 94° to 126° Fahrenheit. The quantity of water which issues from these springs is very considerable; and the thawing of the bottom of the glaciers during intense frost, may, I believe, be attributed to the action of thermal waters. On the Italian side of the same range of Alps, particularly at St. Didier, near the steep southern escarpment of Mont Blanc, there are several thermal waters; and further west than the hot springs at Aix in Savoy, other hot springs have been recently discovered near Grenoble. It thus seems probable, that there still exists, under this range of the Alps, one common source of heat, to the agency of which, in remote ages, the mountains originally owed their elevation; for we can scarcely doubt that the hot springs in the Alps, like those in Auvergne, in Italy, or Iceland, derive their great temperature from subterranean fire. This inference is farther supported by the well authenticated fact, that the districts in which the hot springs are situated have been subject to great and frequent convulsions. In the year 1755, the ground in the vicinity of the hot springs of Leuk and Naters, in the Upper Valois, was agitated with earthquakes every day, from the 1st of November to the 27th of February. Churches were thrown down, the springs were dried up, and the waters of the Rhone were observed to boil in several places. The mountain above the warm spring at Naters, is said to have opened and discharged a quantity of hot water.

The hot springs at the feet of the Pyrenees probably derive their temperature from the same source as those of the Pennine Alps. Hot springs also occur in Dauphiny and Provence which have probably a similar source of heat.

What has been here advanced may be sufficient to show the high probability, that the elevation of the vertical beds in the Alps has been effected by subterranean heat,—an agent which we have direct proof, has, in our own times, elevated considerable portions of the crust of the globe; and it were contrary to the rules of sound philosophy to seek for other causes than those which are now existing, when such causes are adequate to the production of the phenomena we observe.

Two cases are mentioned by M. Elie de Beaumont, in the "Mémoires de la Société d'Histoire Naturelle," tom. v, of granite cutting through and covering secondary rocks; such cases, however, demand the strictest scrutiny before the fact can be regarded as well established. In the "Bulletin de la Société Géologique de France," tom. ii, a section is given of the Jungfrau Mountain, in the canton of Berne, representing two cone-shaped masses of limestone penetrating the granite near the summit. I

spent some weeks almost close to the mountain, and studied its structure with particular attention, and I have no hesitation in expressing a decided opinion, that the section is fallacious. The part represented as penetrated by the limestone, is concealed by a covering of eternal snow. The granite, which the author improperly calls gneiss, is small grained: near the foot of the Jungfrau, in the upper part of the valley of Lauterbrun, I observed a vertical junction of limestone and granite. If cone-shaped, protruding masses of limestone are observed in any part of the mountain, they are, I am persuaded, mere spurs from the limestone on the north side, and cover the granite, but do not penetrate into it. The penetration of granite into limestone, represented in fig. 2, of the same plate, is far more probable and intelligible.

Granite veins, in some instances, serve to explain the occurrence of granitic masses occasionally covering strata of more recent origin. Some granite veins may be nearly contemporaneous with the granite itself, or at least with its solidification. Large chasms or fissures, formed while the mass was cooling, may have been filled with eruptions of fluid granite, which, in slowly refrigerating without disturbance, may have allowed the chemical affinities to separate the constituent parts into larger crystals than what occur in the mass. Thus in the granite veins in the vicinity of Aberdeen, the felspar and mica are crystallized in distinct concretions of very considerable size. At Mousehole, in Cornwall, (before referred to,) the granite veins are composed of very small-grained granite, which have penetrated both the granite and the schist which covers it, at a period subsequent to the consolidation both of the granite and the schist. Now, if granite be the foundation rock on which other formations rest, in almost every part of the globe that has hitherto been examined, we need not be surprised if subterranean heat, which is so extensively operative, has, in some situations, melted the granite already consolidated, and forced a portion of that rock, in a state of fusion, over the upper strata. It is, however, probable, from reasons that will be afterwards stated, that the form which granite would take on its second consolidation, would be generally that of porphyry. This, in many instances, is only a very fine-grained granite, approaching to the state of a compact rock, in which larger crystals of felspar are imbedded. Porphyry of this kind is not unfrequently associated with granite: porphyry, in other instances, is intimately connected with trap rocks, as will afterwards be shown. It has already been noticed, that volcanic fires have pierced through the granite of Auvergne, and, in some instances, the granite has been partially fused, and raised up in rounded or dome-shaped mountains; the granite having been changed into trachyte or volcanic porphyry. This change

or reformation of granite, may, in some instances, have taken place at a recent geological epoch; but it does not appear to me to oppose the propriety of classing granite as the first primary foundation rock. Granite is too extensively spread over the globe, as the lowest accessible rock, to admit of our regarding it as an accidental protruded mass, sometimes found under other rocks more ancient than itself.

CHAPTER VI.

ON GNEISS AND MICA SLATE, AND THE ROCKS WHICH ARE ASSOCIATED WITH THEM.

On the Passage of Granite into Gneiss.—Gneiss and Granit veiné.—Mica Slate.—Formation of Gneiss and Mica Slate—they are not stratified but stratiform.—Talcous Slate, and Chlorite Slate.—Crystalline Limestone, denominated Primary, occurs both in Primary and Secondary Mountains.—Formation of Limestone and Coral Islands by Animal Secretion.—Dolomite, or Alpine Magnesian Limestone.—Serpentine and Ollite, or Potstone.—Euphotide or Saussurite, the hardest and heaviest of Rocks.—Trap Rocks changed to Serpentine.—Eurite or White Stone.—Primary Porphyry a Mode of Granite.—Recurrence of the same Rocks in Rock Formations of different Epochs.

The principal primary rocks enumerated with granite in the preceding chapter, were Gneiss and Mica slate. With these, certain rocks are frequently associated, and are therefore regarded as primary; for where one rock occurs imbedded in another, it is evident that the enclosed rock must be as ancient as the rock which enfolds it, unless the imbedded rock has been subsequently protruded within more ancient rocks, as is the case with some volcanic or trap rocks.

Gneiss received its name from the German miners; according to Mr. Jameson, the decomposed stone on the sides of some metallic veins was first so called; but Werner designated by this term a schistose or slaty granite, abounding in mica. Granite frequently passes into gneiss by an almost imperceptible gradation: where the quantity of felspar decreases, and the crystals or grains become smaller, if the mica increases in quantity, and is arranged in layers, the rock loses the massive structure, and becomes schistose; we have then a true gneiss. By the reverse of this process, if the quantity of felspar increases, and the mica diminishes, the rock loses the schistose structure and becomes massive, and we have granite again. Some geologists call this secondary granite; but the upper and lower granite, and the gneiss, are, in this instance, but different modes of the same rock.

The granite of the Alps, which Saussure calls *granit veiné*, is properly an incipient state of gneiss; the mica is arranged in nearly parallel lines, placed at some distance from each other, which gives to the rock a striped or veined appearance. When these lines of mica approach very near, and form a considerable part of the mass, the rock becomes gneiss. When the mica becomes very abundant, and the other constituent parts are small in size and quantity, gneiss passes into mica slate:—gneiss has often a waved form: but thick masses or laminæ of quartz are fre-

quently interspersed between the felspar and mica, and make the beds very irregular: sometimes the felspar occurs in thick masses nearly pure.*

Beds of crystalline limestone, and of hornblende rock, are frequent in gneiss. It contains most of the metallic ores both in veins and beds. Crystals of garnets are found interspersed in gneiss, but are more common in micaceous schist, which is nearly allied to this rock.

The declivities of granite mountains are covered by rocks of gneiss in many parts of the world. Gneiss constitutes the principal rock formation in a considerable part of Sweden. It occurs in Scotland and Ireland, but is scarcely known in any part of England or Wales. Very well characterized gneiss occurs in the vicinity of Aberdeen. An imperfectly formed gneiss is found on the Malvern Hills. I have also seen gneiss brought from the lower part of Skiddaw in Cumberland. Mountains of gneiss are not steep and broken as those of granite, and the summits are generally rounded.

Mica slate, or *Micaceous Schistus*, is frequently incumbent on gneiss, or granite, and covered by common slate: it passes by gradation into both these rocks—the coarser grained resembling gneiss, and the finer kind, by insensible transition, becoming clay slate.

Mica slate is essentially composed of mica and quartz intimately combined; the felspar, which is a principal constituent part of granite and gneiss, occurs only occasionally in irregular masses in this rock. The color of mica slate is generally a silvery or pearly white, inclining to a bluish grey or a light green; it sometimes is nearly black, and, when weathered, is generally yellow. I have a specimen of mica slate from North America, which has the purple color of the amethyst; but such deviations from the common colors are rare.

Crystals of garnet are frequently disseminated in mica slate: it contains occasionally crystals of other minerals. It has a slaty structure, and is often waved and contorted, and divided by thin laminæ of quartz. It sometimes contains beds and laminæ of crystalline limestone, or is intermixed with serpentine. Mica slate also frequently contains beds and veins of metallic ores. The gradation of mica slate into gneiss and clay slate, and the transition from granite to mica slate, may be distinctly seen in some of the rocks near Bray, in the county of Wicklow, in Ireland, where I observed that the beds of mica slate adjoining the

---

* The partings or divisions in rocks, which may properly be denominated rents, are distinct from those which are the effect of crystallization, and may be distinguished by their irregularity, roughness, and the indeterminate manner in which they intersect the stone. Some partings have evidently been the result of mechanical causes.

granite, are traversed by numerous and large seams of quartz, running parallel with the slaty structure of the rock, and increasing in size as they approach the granite. The quartz has a greasy aspect, and is evidently of contemporaneous formation with the mica slate and granite.

Mica slate has a near affinity to clay slate; and as I have arranged the latter with rocks of the second class, it may perhaps be doubted whether mica slate should not also have been transferred to the same class. No well characterized rocks of mica slate, of any extent, occur in England. I noticed a micaceous rock, which may be considered as an imperfect kind of mica slate, near the granitic rocks of Mount Soar Hill; but it was covered by wood, which concealed its junction with other rocks. On the western side of Anglesea, near Holyhead, there are numerous rocks of an intermediate kind, between mica slate and talcous slate. The laminæ are separated by very thin seams of quartz; and I observed some of them bent and contorted in various directions, as is not unfrequently the case with mica slate in other districts.

The mica slate on the opposite coast of Ireland, near Bray, I am inclined to consider as of the same formation with that in Anglesea. Probably this rock stretches under the Irish Channel, of which it may form the bed in that parallel of latitude. The structure of both rocks is the same, presenting the same divisions by thin laminæ of quartz, but the mica of Anglesea is more combined with talc. Mica slate abounds in the Highlands of Scotland, and in many alpine districts in Europe, particularly in the Pennine Alps.

Gneiss and mica slate are nearly allied to each other and to granite. Circumstances attending the formation of granite appear to have produced a different arrangement of the component ingredients. This is the more probable, as both gneiss and mica slate sometimes graduate into granite, and have at other times a porphyritic structure. In some situations, the causes which change granite into gneiss or mica slate, have not operated; and we find neither of these substances separating granite from the rocks of the next class.

An opinion has been advanced by Dr. MacCulloch, that gneiss and mica slate have been deposited by water, though he admits the igneous formation of granite: but granite is known, as before stated, to vary much in the proportion and size of its constituent minerals, even in the same rock. Now wherever the felspar was deficient, and the mica and quartz abundant, or where the felspar was more granular, and the mica abundant, the same process that formed granite in one part of a rock, would form gneiss or mica slate in another. Every one who has examined the *granit veiné* of the Alps *in situ*, will admit that it had the same origin as com-

mon granite; and again, they could scarcely hesitate to say, that gneiss and *granit veiné* are only mere varieties of the same rock, and must have had one common origin. The mica in gneiss is as much an igneous formation as that in granite, or in some volcanic rocks.

The influence which names improperly chosen maintain over scientific investigations, is remarkably exemplified in the case of gneiss and granite. Had the former been called (what it really is) schistose granite, much discussion, respecting the different origin of the two rocks, might have been spared: so likewise, when gneiss and mica slate have been placed among stratified rocks, much confusion might have been avoided by designating them merely as *stratiform*. By stratified rocks is generally understood a succession of layers formed by sedimentary deposition; but there is no more reason to believe that beds of gneiss were deposited in this manner, than that lava or granite, which are sometimes stratiform, were originally sedimentary depositions.

Gneiss and mica slate being nearly similar in their constituent parts and geological position, most of the metallic ores and minerals found in one rock, occur also in the other. Crystalline limestone, hornblende, talc, and serpentine, more frequently form beds in mica slate than in gneiss. The waved structure is very common in mica slate, and the beds are often most singularly bent and contorted.

Talcous Slate and *Chlorite Slate* appear to be different modifications of the same mineral substances: in the former the structure is laminated, in the latter it is minutely laminated or granular; the prevailing color of both inclines to green. These rocks are soft and saponaceous to the touch, and sectile. Mica slate appears to graduate into talcous slate, particularly in the vicinity of Mont Blanc. In Cumberland and Scotland, talcous and chlorite slate pass into common roof slate, and alternate with it: the change appears to be owing to a greater mixture of magnesian earth in talc slate, than in common slate. Some varieties of chlorite slate are harder and darker, and approach nearly to hornblende slate. The passage from talcous slate to serpentine forms potstone. Talcous slate frequently occupies the place of mica slate in primary mountains, and is sometimes confounded with it; the two minerals, talc and mica, nearly resembling each other. See Chap. III. The large plates of mica, which are made to supply the place of glass in some lanterns, and in the slides for microscopes, are always miscalled talc. Sometimes mica slate, from an intermixture with talc, forms an intermediate rock, which partakes of the characters of both rocks: such mica slate has generally a greenish color, and is softer than common mica slate.

Crystalline or Primary Limestone, of which statuary marble is a variety, forms beds in several primary rocks. Beds of this

mineral occur more rarely in granite than in gneiss; they are most common in mica slate, with which rock it is often much intermixed, and often alternates with it. It is observed that the primary limestone in granite and gneiss is coarser grained than that in mica slate or common slate. Primary limestone is much intermixed with serpentine. When beds of primary limestone occur of considerable thickness, they sometimes contain veins of metallic ores.

Crystalline or primary limestone, when pure, is composed of calcareous earth, which scarcely exists as a component part of granite, gneiss, or mica slate. No organic remains are found in the crystalline limestone in primary mountains; the structure is granular; the white variety, known as statuary marble, resembles fine loaf-sugar, and is imperfectly translucent; hence it has been called by the French, *chaux carbonatée saccaroide.* The color of primary limestone is sometimes yellowish, greenish, or inclining to red. From a mixture of mica, it has often a slaty fracture, and divides in plates. It may be further deserving notice, that primary limestone, or statuary marble, frequently contains a considerable quantity of siliceous earth, to which it owes its hardness and durability.

Neither in England nor Wales have any rocks of limestone been found, which possess the crystalline translucent qualities of statuary marble, though very beautiful marbles occur, which will receive a high polish; these belong to the limestone which will be described in the following chapter. White marble is procured from Italy, Switzerland, and the Grecian Archipelago.

Imperfectly white crystalline limestone occurs in different parts of Scotland intermixed with serpentine and mica slate. Crystalline limestone is also found in the Hebrides, particularly in the Isle of Sky; but it well deserves attention, that this limestone, in the latter island, evidently appears to be secondary limestone (lias) changed in its character by its contiguity to trap rocks, which were in all probability in a state of igneous fusion. In other alpine districts, the limestones called primary appear also to have derived their crystalline character from the action of igneous rocks in their vicinity, and hence ought not to be classed with primary formations. I have seen many beds of extremely hard white limestone in the Alps, which have all the characters of primary limestone, with the exception of being somewhat less granular. These beds occur over other beds containing the fossils found in green sand, and may therefore be classed with chalk. That the highly crystalline limestone which occurs near primary mountains has been in a state of fusion, is rendered probable by the crystals of garnet and siliceous minerals which are often imbedded in it. These minerals could not have been deposited from an aqueous solution.

It was once supposed that all calcareous rocks and strata were composed of the shells of marine animals, and it cannot be doubted that many of them are entirely formed of these organic remains: but in the beds of primary limestone, and even in some of the secondary limestones, no vestiges of such remains occur. It may be said that the process by which primary limestone was crystallized, destroyed all traces of organization; and though it would be impossible to disprove this, yet there is no reason to believe that lime may not exist as an elementary earth, like silex or alumine, independent of the operations of animal life. It does so exist as a component part of many minerals, and it may have existed in sufficient quantity to form the mountains of primary limestone.

It is, however, a curious but undoubted fact, that no inconsiderable portion of the earth's surface has been formed by organic secretion; and the process is still going on extensively in the Pacific and Indian seas, where multitudes of coral islands emerge above the waves, and coral shoals and reefs occur at small depths beneath the water, in which, according to the observations of MM. Quoi and Gaimard, the animals may be seen. "Some spread out into fans, or ramify into trees; some are round like balls; their varied and elegant forms mingle and blend together, and reflect the varied hues of red, blue, and yellow." As one generation dies and leaves its calcareous remains, another succeeds, until the mass of coral is raised to the surface, when the formation ceases. Fragments of coral are afterwards broken off by the waves during storms, together with shells, weeds, and sand, and are driven upon the other parts of the island, and continue to elevate it until the surface is raised above the reach of their action. From the accounts of the above naturalists, and the more recent observations of Captain Beechy, it appears, that the species of polypi that chiefly form coral islands, do not exist at greater depths than a few fathoms below the surface;* therefore, the deep soundings taken near these islands prove, that coral forms the crests of steep submarine mountains, which were probably volcanic, as these crests have frequently a circular shape, but are open on one side, leaving a passage to a circular lagoon or lake within, which is shallow, and supposed to fill the crater of a submarine volcano. Though the beds of coral that form islands are not of the vast thickness which had been supposed, yet they rival, in extent and magnitude, some of the large calcareous formations of our present continents. In some coral islands, the coral rock, which must have been formed under the sea, is now considerably elevated above the surface. It has been conjectured,

* The accuracy of this conclusion has been disputed; for some species of coral are brought up by soundings, from the depth of one hundred fathoms or more.

that they were upheaved by volcanic agency: this opinion seems now fully confirmed, by observations recently made on coral islands in the southern Pacific, after the great earthquakes in 1835. Beds of oyster shells, many miles in length, are also known to occur in European seas; thus millions of small marine animals are preparing future abodes for other classes of animals of larger size, and living in another element. From whence do these innumerable zoophytes and molluscous animals procure the lime, which, mixed with a small portion of animal matter, forms the solid covering by which they are protected? Have they the power of separating it from other substances, or the still more extraordinary faculty of producing it from simple elements? The latter I consider as more probable; for the polypi which accumulate rocks of coral have no power of locomotion: their growth is rapid; and the quantity of calcareous matter they produce, in a short space of time, can scarcely be supposed to exist in the waters of the ocean to which they have access, as sea water contains but a minute portion of lime.

It is now ascertained that lime and the other earths are compounds of oxygen united with metallic bases; and the brilliant discoveries of Sir H. Davy respecting the metallic nature of ammonia, would lead to the conclusion, that the metallic bases of all the alkalies and alkaline earths, which have many properties in common, may, like ammonia, be compounds of hydrogen and azote, but differently combined. Now it is well known that hydrogen and azote, which exist as elementary constituent parts of almost all animal substances, may be derived from water and the atmosphere; and should the compound nature of the metallic bases of the earths be ascertained, the formation of lime by animal secretion will admit of an easy explanation. There can, however, be little doubt that lime exists as an elementary constituent part of the globe, as much as any of the other earths that form rocks.

Dolomite, so called in honor of the French geologist Dolomieu, is a variety or modification of limestone; it contains 48 parts of magnesian earth, combined with 52 parts of calcareous earth. Dolomite is found in rocks of different classes; that which occurs at St. Gothard, and other parts of the Alps, closely resembles white primary limestone: it is minutely granular, and the grains are easily separated by the finger; but some varieties are harder. Dolomite, and the magnesian limestones in the secondary strata, dissolve with more difficulty in acids than common limestone. Dolomite forms vast beds in the western Alps; it occurs also in various parts of the Apennines; in Carinthia there are entire mountains of dolomite. The beds of Alpine dolomite are often much broken, apparently by the protrusion of beds and masses of porphyry. The eminent geologist Von Buch maintains

that limestone has been converted into dolomite by its proximity to porphyry in fusion, and that the magnesia has been transferred from magnesian minerals in the porphyry to the limestone; the magnesia being reduced to vapor or gas. Great difficulties attend this theory: I shall hereafter notice situations in England, where the theory might be subjected to the test of direct experiment. For the present it may be sufficient to notice, that many strata of magnesian limestone appear far removed from the possible influence of igneous rocks. Magnesia is found in many earthy minerals, and may be regarded as a constituent element of the globe.

Serpentine derives its name from its variegated colors and spots, supposed to resemble the serpent's skin: its chemical composition has been before described. The colors are most generally various shades of light and dark green, which are intermixed in spots and clouds; some varieties are red. When fresh broken, it has some degree of lustre, and a slightly unctuous feel; when pounded, the powder feels soapy. It is harder than limestone, but yields to the point of a knife, and will receive a very high polish. When serpentine is found intermixed with patches of crystalline white marble, it constitutes a stone denominated verde-antique, which is highly valued for ornamental sculpture. Some varieties of serpentine are translucent; in others, there is appearance of crystallization, forming a mineral called diallage, or schiller spar. The minerals associated with serpentine are generally those allied to talc. Compound rocks, in which talc and hornblende are predominating ingredients, pass into serpentine. Magnesia enters largely into the composition of these rocks. A late analysis of one kind of serpentine, gave 48 per cent. of this earth. Serpentine commonly occurs in gneiss and mica slate, in beds which are sometimes so thick as to compose mountain masses of considerable height. Serpentine sometimes becomes magnetic, from an intimate intermixture with minute particles of magnetic ironstone. Many of the alpine districts in Europe contain rocks and beds of serpentine; but, according to Patrin, there is no serpentine in Northern Asia, nor was it seen by Humboldt in the Andes; it is not uncommon in the United States of North America. In the Alps, it is observed that the rocks of serpentine lie principally on that side which faces Italy, and the coast of Genoa. There is a soft kind of serpentine, sufficiently tenacious to be turned in a lathe into vessels of any shape, which resist the action of fire: hence they are used for culinary and other purposes in some parts of Switzerland, in Lombardy, and even in Higher Egypt. The use of this stone is of great antiquity, being distinctly mentioned by Pliny; it is called *lapis ollaris*, or potstone.

In Cornwall, serpentine occurs with a micaceous rock lying over granite, and forms part of the promontory called the Lizard Point. It occurs, also, near Liskeard, in the same county. It is

not met with in any other part of England, that I know of; but I have observed rocks approaching the nature of serpentine in Charnwood Forest, and in the county of Radnor, in Wales.

Beautiful varieties of red and green serpentine occur in the Isle of Anglesea, about six miles from the Paris copper mine. It is found in beds of great thickness, associated with the common slate rocks of the district, which approach in their nature to talcous slate: asbestus lies in considerable quantities in the partings between the beds of serpentine.

Some of the specimens of this serpentine have the characters of the precious or noble serpentine; the colors are principally dark green, intermixed with spots and clouds of lighter green, and shining laminæ of schiller spar, or crystallized serpentine. The fracture is conchoidal, and it is translucent at the edges. It resists the point of a copper or brass tool, and breaks with great difficulty. Some varieties contain crystalline limestone, but in smaller patches than in the Italian verde-antique; occasional stripes and spots of steatite, asbest, and quartz, occur in it. The red is sometimes intermixed with a great variety of other rich colors in the same stone, as black, white, greenish white, and dark green. It may be considered as a valuable stone for purposes or ornamental architecture, for in beauty and durability it is not exceeded by the costly marbles of Greece or Italy.

By a mixture of serpentine with talc or steatite, serpentine becomes soft and sectile, and forms the mineral called potstone, before mentioned. A different combination of crystallized serpentine (*diallage*) with jade, or felspar, forms one of the hardest and heaviest of known rocks. It was first noticed by Saussure in rounded pieces and loose blocks, scattered over several parts of the valley near the Lake of Geneva: to this mineral the name of Saussurite has been given. It is much harder than quartz, and its specific gravity is 3.35: it is the hardest and heaviest of known rocks composed only of earthy minerals; the color generally is greenish. Some varieties of saussurite, as well as of serpentine, acquire an external polish, like a coat of varnish, by exposure to the action of water: this may be observed in the pebbles of bright green saussurite near Mont St. Gothard, and in the serpentine at the Lizard in Cornwall. For a considerable time it was unknown where saussurite occurred *in situ;* it has since been discovered in immense beds, associated with serpentine, in the valley of Sass, in the Haut Valois. Near Nyon, on the Lake of Geneva, one hundred and twenty miles distant, there is a field scattered over with large blocks of the same stone, which the proprietor has been unable to remove by blasting, on account of their unconquerable hardness. Beds of saussurite occur on the southern side of the Alps, and in the Apennines. A very interesting description of the saussurite and serpentine of the Apen-

nines has been published by M. Brongniart, entitled *Sur le Gisement ou Position relative des Ophiolites, Euphotides, et Jaspes, dans quelques Parties des Apennins.** In these mountains, the serpentine rests upon saussurite, the saussurite on strata of jasper, and the latter on secondary limestone. This position is remarkable, for geologists had long supposed that all serpentines were more ancient than the secondary rocks. It has, however, been recently discovered, that some trap rocks which are in contact with beds of limestone, or cut through beds of limestone, are changed into serpentine, apparently by intermixture with calcareous earth. This discovery throws much light on the true nature of serpentine: we can no longer be surprised at finding these rocks in formations of different epochs. Though serpentine may in many instances be considered as a rock whose quality has been changed as before stated, yet it would be contrary to sound induction to maintain that serpentine may not, in other instances, be an original rock formation. Wherever the earths that compose serpentine have occurred together in due proportions, the same causes which have produced other mineral combinations may have formed serpentine: it is rendered almost certain that this has been the case, as many rocks containing chlorite and hornblende, appear to pass by gradation into serpentine.

Hornblende Rock and *Hornblende Slate.*—This mineral has been described Chap. III. When it forms the principal parts of rocks, the color is commonly a greenish black. Massive hornblende in rocks is generally coarsely granular and lamellar; in hornblende slate, it is frequently radiated or fibrous, and when the fibres are very minute, it has a velvet-like lustre. Hornblende slate occurs in beds in granite, gneiss, and mica slate, and occasionally in common slate: it appears to pass by gradation into serpentine: the change is effected by an increase of magnesia, which forms one of the constituent parts of hornblende.

Hornblende, in large lamellar grains, intermixed with felspar, forms sienite, which it was remarked, in the last chapter, is not unfrequently associated with granite: the passage of one rock into the other, by the increase or decrease of felspar, may frequently be observed in the same mountain. When hornblende and felspar are more intimately blended, they form the rock called by the Germans *Green-stone*, by the French *Diabase;* and, with other rocks of similar composition, are frequently described as trap rocks, and by the French as *roches amphiboliques:* these will be more properly noticed in the subsequent chapters. When the hornblende and felspar are so closely and minutely in-

* It is to be regretted that so excellent an observer and mineralogist as M. Brongniart, who is so justly eminent for his scientific labors, should have thought it necessary to burden Geology with two additional new names. Serpentine he has denominated *ophiolite*, and saussurite *euphotide*.

termixed, that the rock appears homogeneous, the trap has all the external character of a rock (hereafter to be more fully described) called Basalt.* In examining the geological specimens of the late M. de Saussure, in the museum at Geneva, I observed that the rocks which he so frequently mentions under the name of *Cornéene*, are mixtures of hornblende and felspar, in which the former mineral predominates.

Hornblende intermixed with felspar, forming sienite and greenstone, occurs at the Malvern Hills, in Worcestershire; at the Charnwood Forest hills, in Leicestershire; and in Cornwall, Cumberland, and North and South Wales. Very little well characterized hornblende slate is found in any part of England, but it occurs abundantly in the alpine parts of Scotland, and in most of the principal mountain ranges in Europe. The various intermixtures of hornblende and felspar, to which the name of trap rocks is frequently given, may more properly be classed with transition rocks.†

Porphyry derives its name from a Greek word denoting *purple;* the rock to which it was at first applied had a purple color. In the modern acceptation of the term, any rock which is compact, or finely granular, and contains distinct imbedded crystals, is called porphyry, whatever be its color. The base or paste of most porphyritic rocks is felspar; and the imbedded crystals are also felspar, though there may be also small grains or crystals of quartz or other minerals. It has been stated, in the preceding chapter, that granite, by becoming finer grained, frequently passes to the state of porphyry. The *eurite* of the French geologists, and the *weiss-stein* or *white stone* of Werner, is a granite in which the felspar is the principal constituent part, and is either finely granular or nearly compact. To this variety English geologists give the name of compact felspar: the white elvan of the Cornish miners is a porphyritic eurite.

---

* The rock to which the French give the name of Diabase, the compact trap of Werner, resembles basalt (which the French call Dolerite) so closely, both in composition and physical characters, that the division into two species seems principally made to serve the purpose of theory. Diabase is composed of felspar and hornblende, and dolerite of felspar and augite intimately combined. But as hornblende and augite do not differ more in chemical composition, than one species of hornblende differs from another, and as these two minerals are only to be distinguished by their crystallization; when they occur uncrystallized, may they not be regarded as identical? It is true, augite occurs abundantly in rocks of undoubted igneous origin, and in the lavas of recent volcanoes; hornblende occurs also in basaltic lavas, but more frequently in rocks of which the igneous origin is not so generally admitted: yet it may be fairly doubted, whether the distinction between compact diabase and compact dolerite, has not been made, in order to form gratuitous conclusions respecting the different origin of rocks, which are, in chemical composition and external characters, essentially the same.

† Dr. MacCulloch states an instance in Shetland, where slate (clay slate) appears to be converted into hornblende slate by approximating to granite; but no inference can be fairly drawn from a solitary instance of this kind, as there is no evidence to prove that the hornblende slate is not an original rock.

Geologists have described four formations of porphyry, but it is generally agreed that there is much uncertainty with respect to the situation of these formations. The porphyry which occurs regularly imbedded in granite, or which appears to be formed by a mere change of structure in that rock, may properly be classed with primary rocks: it is not considered to be an extensive formation; the white elvan of Cornwall, and probably the porphyry associated with mica slate in Argyleshire, belong to this formation. Porphyry also occurs in enormous masses, sometimes intersecting and sometimes covering primary mountains. The granite of Ben Nevis in Scotland is intersected by veins of porphyry; and at the head of Glen Ptarmagan, a cliff of porphyry 1500 feet high, shaped like an oblique truncated pyramid, passes through granite.* Porphyry, imbedded in transition rocks, or associated with trap or volcanic rocks, must generally be regarded as contemporaneous with the formations in which it occurs. Porphyry is in some instances an undoubted volcanic formation, and presents a connecting gradation between granitic primary rocks and those of a more recent igneous origin. Wherever porphyry occurs unconformably, covering other rocks, it is evidently more recent than the rocks on which it rests, and must be classed with basaltic or trap rocks; this porphyry will be described with them in a subsequent chapter.

Before taking leave of the rocks classed as primary, it may be proper to notice that some of the rocks associated with granite, gneiss, and mica slate, occur also in the transition class, and even in the lower secondary strata. The same causes by which they were formed among primary rocks, have also operated at a later period: indeed, one of the well known rocks, limestone, has been deposited or formed in all the different classes of rocks except the volcanic, and must therefore receive its name from the class with which it is associated; as primary limestone, transition limestone, &c. In some instances, the mineral characters, or the fossils, serve to distinguish rocks of the same kind that occur in the different classes or formations: thus the rocks associated with primary rocks are generally harder and more crystalline than the same species of rock which occurs in the secondary class; but this is not invariably the case.

---

* Phil. Mag.

CHAPTER VII.

ON TRANSITION ROCKS, AND ON THE PROBABLE CONDITION OF THE SURFACE OF OUR PLANET DURING THE TRANSITION EPOCH.

Transition rocks intermediate between the primary and secondary.—Their characters.—Slate or clay slate.—Peculiarities of structure.—Varieties of slate.—Greywacke and greywacke slate.—Passage of into red sandstone and gritstone.—Conglomerate and sedimentary transition beds intermixed with trap rocks.—Lower transition limestone; contortions of, and remarkable position of its beds.—Upper transition or mountain limestone contains beds of magnesian limestone.—Errors respecting the mountain limestone of Derbyshire.—Changes and anomalies in the stratification of mountain limestone.—Structure of Crich Cliff.—Quartz rock, Jasper, Green-stone.—On conformable and unconformable igneous rocks intermixed with transition rocks.—Transition series of Cumberland and Yorkshire, different from those of Shropshire and Wales, called Silurian rocks.—Thickness and extent of the Silurian beds.—On the temperature of the globe and the animals of the transition epoch.

In many mountainous districts the primary rocks, described in the preceding chapters, rise in peaks or mountain masses, uncovered by rocks of a more recent formation. In other situations they are covered by rocks of different geological epochs, or by diluvial beds of clay and gravel, and sometimes by beds of lava. More commonly, primary rocks are succeeded by rocks which bear a close resemblance to them, and pass by gradation into them. These rocks have been called intermediate or transition rocks. In England and Wales they compose the highest mountain ranges, extending from Cumberland to Devonshire. It is in some of the transition rocks, that the fossil remains of animals and vegetables are first discovered; they may, therefore, be regarded as the most ancient records of organic existence on our globe. Transition rocks also contain the richest repositories of metallic ores. Metallic veins rarely occur in secondary rocks.

When geology first attracted attention, it was found difficult to draw a well marked line of distinction between primary and transition rocks. The difficulty arose chiefly from arranging slate with primary rocks. Organic remains sometimes occur in slate rocks; the terms "newer and older primary slate," and "transition slate," were introduced; between these, no difference could be discovered, except the occasional occurrence of organic remains. I have long deemed it desirable to separate slate from the primary class, for reasons given in the former editions of this work, but which I shall again state, as some geologists of eminence in this country still class the lower slate rocks in which fossil remains have not been found, as primary: but

this is an uncertain character; for slate that contains no fossils in one situation, may be found to contain them elsewhere. It is, however, of little importance, in which class slate is arranged, if its geological position and characters are accurately given. The propriety of classing slate with primary rocks has long been doubted by continental geologists.

One of the disciples of Werner, M. D'Aubuisson, admits that there is no where any extensive formation of primary slate. M. Bonnard, another disciple of the same school, in his *Apperçu Géognostique des Terrains*, after enumerating various primary slate rocks, candidly acknowledges that it is doubtful whether primary slate can any where be found. It is true, that mica slate passes by almost imperceptible gradations into common slate; but here, as in other instances, we only find that Nature is not limited by the artificial arrangements of the geologists; yet, so long as it may be proper to class rocks containing organic remains with transition rocks, we must place slate among them. Nor can this be invalidated by the fact, that in some slate rocks, no vestiges of animal or vegetable remains occur; for among the secondary strata, abounding in such remains, we often meet with alternating beds, in which they are never found; but we do not, on that account, class them with primary rocks. In arranging transition rocks, I most decidedly place the English mountain limestones among them, as I have done in the former editions of this work. I know no circumstance in Geology that evinces more strongly the tenacity with which errors are cherished, when they have been some time entertained, than the determination of English geologists to separate mountain limestone from transition limestone, in opposition to analogy, and to the universal opinion of geologists on the Continent. This separation, as a mere matter of classification, would be in itself of little importance; but it has tended, more than any other circumstance, to perplex both foreign and English geologists in their attempts to assimilate the rock formations of England with those on the continent of Europe.

When a general attention was first excited in this country to the study of Geology, access to the Continent was extremely difficult, and we were left to explore, as well as we could, the geology of our own island, enlightened only by the dark lantern of German Geognosy. Many characters were given of transition rocks, and of flœtz or parallel rocks, founded on local observations in Germany, which did not apply to the rocks in other countries; it was found that the characters of our metalliferous limestone did not agree very well with either, and therefore English geologists have retained the name of mountain limestone; and the appellation of transition limestone was restricted to a lower bed, small in extent, and comparatively unimportant.

When I first visited the Continent, in 1819, and examined the cabinets of some eminent geologists, I was particularly struck with finding the *analogues* of our principal beds of mountain limestone exhibited as types of true transition limestone. On my return to Paris the following year, I took specimens of our mountain limestone from Derbyshire, Westmoreland, Somersetshire, and Wales; and also of the lower limestones from Shropshire and Devonshire; and presented them to MM. Brongniart and Brochant. The whole of the specimens they recognized as transition limestones, and selected the encrinal and dark madrepore mountain limestones, as the true types *par excellence des Calcaires de Transition.*

More extended observations have led English geologists to entertain more correct views respecting the class of transition rocks; and it is now generally agreed to arrange with the rocks of this class, all the rocks, from the lowest slate rocks, in which organic remains occur, to the mountain limestone, and the great coal formation, which frequently rests upon it. It may, however, be more convenient to describe the coal formation of England apart from the transition rocks, as forming the separation between them and the rocks of the secondary class.

The following arrangement of transition rocks was considered, till recently, to comprise the most important rocks of this class, but their order of succession was not regarded as regular. A recent examination of the transition rocks of Shropshire and the adjacent counties, by Mr. Murchison, has disclosed a variety of beds in succession, which had before been but imperfectly known. To these beds Mr. M. has given the name of *Silurian*, from the districts in which they occur, being formerly inhabited by the ancient Silures.

A brief account of the Silurian rocks, with some observations upon them, is placed at the end of the present chapter. It may be proper, however, here to state, that they comprise the middle and lower series of English transition rocks.

In the former editions of this work, the principal formations which occur conformably in transition rocks, were stated as under:

1. Slate, including flinty slate, and other varieties associated with slate.
2. Greywacke and greywacke slate, passing into conglomerate and sandstone, called the old red sandstone.
3. Lower transition limestone, sometimes interspersed in the old red standstone.
4. Mountain limestone, alternating with shale, and sandstone or gritstone.
5. The regular coal formation.*

* The regular coal strata or coal measures, where they occur in England, separate the transition from the secondary rocks. If they are classed with either, it should be with the former.

Rocks interposed or covering transition rocks unconformably.

1. Porphyry, passing into trap or greenstone.
2. Clinkstone, passing into basalt and other trap rocks.

Slate, of which roof slate is a well known variety, has been already described as a simple mineral. See Chap. III. It is called by the Germans *Thon-schiefer* or *clay slate;* by ancient English geologists, argillaceous schistus; by the modern French, *Phyllade*. The term *slate*, is perhaps the most proper that can be used to designate this rock, as the best variety of it, roof slate, is well known. Clay slate is a name given from an erroneous opinion respecting its constituent parts; and the term is liable to create much confusion, as the softer kind of slate in the coal strata, is called slate clay. I shall, therefore, throughout the present volume, substitute the term *slate* for clay slate, and for slate clay the more intelligible English term *shale*.

Slate rocks abound in most alpine districts, resting either on granite, gneiss, or mica slate. That slate which lies nearest the primary rocks has a more shining lustre than the other, and partakes more of the crystalline quality of mica slate. As this rock recedes from the primary, its texture is generally more earthy. Its colors are various shades of grey, inclining to blue, green, purple, and red. Some kinds of slate split into thin laminæ, which are well known as forming roof slates. Slate rocks are commonly divided into beds of various degrees of thickness, which generally are much elevated, and from the natural divisions of the rock, they often form peaked and serrated mountains.

Slate has been generally described as distinctly stratified because it splits easily into thin laminæ, and the direction of the laminæ is asserted to be in the direction of the beds; but, in opposition to the authority of many eminent geologists, I maintain that slate, unless it be of a soft or coarse kind approaching to shale or greywacke, invariably splits in a transverse direction to that of the beds, making with that direction an angle of about sixty degrees: it has frequently two distinct cleavages.*

Few persons, perhaps, have examined more slate rocks, or consulted more workers in slate quarries, than I have; and the fact respecting its cleavage is invariably what is here stated, except in very coarse greywacke slate, and soft slate or shale.

Slate rocks vary much in quality in the same mountain; those which contain a great quantity of siliceous earth pass into flinty slate. When magnesia enters largely into the composition of

---

* Professor Sedgwick, in a paper on the structure of large mineral masses, (see Geological Transactions, Second Series, vol. iii,) refers to, and confirms my views respecting the crystalline cleavage of slate rocks. These views were stated in the first edition of this work in 1813, in opposition to the generally received opinion, that the slaty cleavage was the result of stratification. In plate 3, fig. 1, *d.d*, the planes of cleavage in slate rocks are represented as distinct from the planes of stratification.

slate rocks, they are distinguished by their green color, and pass into chlorite or talcy slate,—a rock before mentioned as occurring also in primary mountains. Whetstone slate, or hone, is a variety of talcy slate, containing particles of quartz; when these particles are extremely minute, and the slate has a uniform consistence and requisite degrees of hardness, it forms hones of the best quality. Carbonaceous matter is first discovered in slate rocks, and increases in quantity as they approach the secondary strata. Drawing slate is stated to contain 11 per cent. of carbon; where the carbon is very abundant, the slate has a dark color, and is generally soft. Impressions of vegetables are found in some slate rocks that were formerly regarded as primary; the slate rocks in the vicinity of Mont Blanc and Mont Cenis, contain impressions of ferns. Slate contains occasionally impressions of fuci, or sea weed.

That fine variety of slate which is used for roof slate, seldom forms entire mountains, but is generally imbedded in slate rocks of a coarser kind: the beds of roof slate are sometimes of considerable thickness, and generally rise at an elevated angle. If geologists had not been induced, by an attachment to theory, pertinaciously to adhere to opinions once received, they could not have failed to recognize the effect of crystallization in the cleavage of slate, as evidently as in the laminar divisions of felspar.

Those varieties of roof slate are preferred for the covering of buildings that are the least absorbent of water, and have the smoothest surface, and split into the thinnest plates; they are, however, frequently made too thin to be durable, and too light to resist the force of the wind during storms.

Quarries of slate are worked extensively in Westmoreland, Yorkshire, Leicestershire, North Wales, Cornwall, and Devonshire. The foreign localities of slate are so numerous, it would be superfluous to name them.

Mountains of slate are seldom so precipitous as those of granite, but have often a sharp serrated outline. They are covered with verdure on their declivities, as they contain silex, and a more equal admixture of the earths favorable to vegetation.

Flinty slate, as before observed, differs from common slate by containing a greater quantity of siliceous earth; and, as its name implies, it partakes of the nature of flint. Slate and flinty slate not only pass into each other, but frequently alternate. When the latter ceases to have the slaty structure, it becomes hornstone, or what the French denominate petro-silex. If it contain crystals of felspar, it becomes hornstone porphyry; all these varieties may be observed alternating with each other in the same rocks in Charnwood Forest, and in North Wales and Cumberland.

Slate is regarded as one of the most metalliferous rocks: nearly all the principal metallic ores have been found in slate, either in

veins or beds; but it is remarkable, that flinty slate seldom contains any repositories of metallic matter. Lead and copper are the principal metals found in the slate rocks of England and Wales; they are not so rich in lead as the mountain limestone, but the lead ore in slate rocks contains a larger portion of silver. The killas of Cornwall, so remarkably metalliferous, is a variety of slate.

It seems now to be admitted by geologists, that slate is a sedimentary rock, formed by the deposition of minute particles of the primary rocks, in the state of mud, which has been subsequently consolidated by heat and pressure: in those slate rocks which contain vegetable or animal remains, we can scarcely conceive of any other mode of formation. Many slate rocks, however, in which no such vestiges of organic existence occur, may have been deposited by subterranean eruptions of water and earthy particles, and may be as original formations as any of the lower rocks of igneous origin. In some instances the muddy depositions have become intermixed with the matter ejected by submarine volcanoes, or with fragments and particles of more ancient rocks, which have been broken and distributed by some of the great terrestrial convulsions that have taken place during the transition epoch. It is this intermixture which has produced the varieties of greywacke rocks, which pass from a coarse slate into conglomerate rocks, and in other cases seem to be composed of an intermixture of slate and sand, differing little from sandstone. Again, we find volcanic or trap rocks so intermixed with sedimentary and sandy particles, that it is difficult to determine whether they partake more of an aqueous or igneous origin: such rocks are not unfrequently met with among the transition rocks of England.

Greywacke and *greywacke slate;* German *grauwacké.* This dissonant term, which we have borrowed from the German, the French geologists have exchanged for a name not more harmonious, though more expressive, *Traumate,* from the Greek *Thrausma,* a fragment.

Greywacke, in its most common form, may be described as a coarse slate containing particles or fragments of other rocks or minerals, varying in size from two or more inches to the smallest grain that can be perceived by the eye. When the imbedded particles become extremely minute, greywacke passes into common clay slate. When the particles and fragments are numerous, and the slate in which they are cemented can scarcely be perceived, greywacke becomes coarse sandstone or gritstone. When the fragments are larger and angular, greywacke might be described as a breccia with a paste of slate. When the fragments are rounded, it might not improperly be called an ancient conglomerate. When rocks of greywacke have a slaty structure, they form greywacke slate.

Greywacke has, by some of the French geologists, been described as a transition sandstone, with a cement, either of siliceous earth or of slate. This definition agrees with the gritstones associated with the upper transition or mountain limestone. Where the paste is hard and siliceous, as I have observed in the greywacke of Savoy, that separates the primary from the secondary rocks, many of the siliceous particles may have been original concretions, formed at the same time as the paste; and where these concretions are all composed of quartz, we may infer that such has been their mode of formation. In other instances, the fragments are evidently the débris of more ancient rocks, that have been broken down by some great catastrophe, and mixed with more recent beds at the period when they were forming. This mode of formation implies, that a considerable period elapsed between the formation of the primary and secondary rocks. The fragments are always those of lower rocks, and never of the upper strata. In some situations, immense beds of loose conglomerate, composed of large fragments and b ulders of the lower rocks, separate the slate rocks from the calcareous formations; such conglomerates may be regarded as occupying the geological place of greywacke, and belonging to the greywacke formation.

The old red sandstone, about which so much has been written, and so little understood, is a greywacke, colored red by the accidental admixture of oxide of iron. In Monmouthshire, the relations of red sandstone with greywacke, and the passage of one rock into the other, may be distinctly observed; the connection also with the lower gritstone, under the mountain limestone, may be plainly traced. Here, then, we have the mountain limestone with its alternating beds of grit, the red sandstone and the greywacke, evidently members of the same formation; and to make the connection more complete, the red sandstone contains beds of limestone, which form the link between the lower transition and the upper transition limestones. This limestone is imperfect, being intermixed with siliceous particles; it is of a greenish color, and hence called Gooseberry limestone. The red sandstone also passes into claystone, which is as well characterized as that of the Pentland Hills. From the quantity of oxide of iron and of red marl in some beds of the old red sandstone, and from its passage into claystone, I am inclined to believe that the red sandstone of Monmouthshire has partly been formed by an intermixture with submarine volcanic eruptions.

The old red sandstone occupies in many situations the geological position of greywacke, and greywacke slate, into which it passes merely by a change of color. The principal reason why it has not been generally recognized as belonging to the greywacke formation is, that it has frequently been confounded with the red

sandstone above the coal formation: some of the beds greatly resemble each other, and it is not yet clearly ascertained, whether the red sandstone in some parts of England and Scotland be the old red sandstone or the new. Until English geologists shall renounce their prejudices, and place the old red sandstone and mountain limestone in the transition class, with greywacke and transition limestone, every attempt will be vain to identify this part of the geology of England with that of the Continent: particularly as the alpine limestone of foreign geologists is a very different formation from the transition limestone, comprising the several formations of limestone above the coal strata, and new red sandstone, or what the French call *Grès bigarré.*

Transition Limestone.—English geologists have until very recently restricted the name to the limestone beds that occur in or below the old red sandstone; these vary considerably, but have generally a sub-crystalline texture, and are of different colors, red, brown, grey, black, or variegated. The lower beds in Devonshire are beautifully veined and spotted, and take a high polish. The transition limestones of Dudley and Wenlock have a light dull grey color, and are less crystalline than those of Devonshire, or than the upper transition or mountain limestone above the old red sandstone.

Transition limestone occurs in beds alternating with slate, greywacke, greywacke slate, and coarse gritstone. Some of these beds are of considerable thickness, and form mountain masses. The lowest beds alternate with slate; they contain few organic remains. The variegated limestone of Devonshire is of this kind. Sometimes numerous thin strata of slate and transition limestone alternate, and are much bent and contorted. A very remarkable instance of this occurs at Drewsteignton, near Moreton, in Devonshire, where a series of thin strata of dark limestone alternate with strata of indurated slate, and are bent and folded in various directions. Were we to take a number of alternating sheets of black and brown paper, and fold them nearly round a wine decanter, and then bend them back over the lower folds, we should have a not unapt representation of the singular contortions of the strata in this place, where they are exposed to view by extensive quarries cut in the rock.

The remarkable contortions of the beds of transition limestone and slate, imply the operation of a cause that could not only bend but soften the strata; and were we to admit that granite has once been in a state of fusion, and been protruded through the outer crust of the globe, the immediate contiguity of these bended strata to the granite of Dartmoor might indicate the agent by which the effects were produced. Near Dudley, in Staffordshire, we have another remarkable instance of the bending of beds of transition limestone; but this is in the vicinity of basaltic rocks, which are now admitted to be of igneous origin.

The limestone at Wren's Nest, near Dudley, consists of two beds—one ten, and the other fourteen yards thick, resting upon beds of soft and imperfect limestone and shale, called *wild measures.* The two beds of limestone are separated by strata of wild measures thirty eight yards in thickness; they are raised up together in a position approaching to vertical, and are folded round the hill, and enclose a space of about fifty acres, with a double wall of limestone rising above the country, like an oval tower widening at the lower part.

If two sheets of pasteboard were separated by a quire of blue paper and laid flat, and a blunt metallic rod were thrust through the whole from beneath, it would force the lower sheet of pasteboard through the upper sheets, and represent the present position of the strata at Wren's Nest Hill. At Dudley Castle Hill, about a mile distant, the beds of limestone are bent, and dip on each side of the hill. (See a section of this hill, Plate III, fig. 4.)

A, Wren's Nest Hill; *a a*, *b b*, the two beds of limestone enfold the hill, as represented in the small compartment E, above the section. The dotted line and open spaces show where the limestone has been quarried away; 1, 2, are deep galleries over each other, along which the limestone is also quarried; the lower is near the level of a canal which penetrates the hill to convey the limestone away: *c*, represents the outcrop of the thirty feet bed of Staffordshire coal, which comes to the surface near Wren's Nest Hill; B, represents the arrangement of the limestone strata at Dudley Castle Hill, similar to that at Wren's Nest Hill; and D, a hill capped with rudely columnar basalt in the vicinity. In this section the proportion of distance has been disregarded, in order to comprise the different objects in one view: the distance between Dudley Castle Hill and Wren's Nest Hill, is about two miles. The strata at Dudley Castle Hill are what is called saddle-shaped, declining on each side of the hill.

The transition limestone of Dudley is not covered by any beds of the upper transition or mountain limestone, but by strata about seventy six yards in total thickness, composed of imperfect limestone and sandstone, which separate it from the lowest coal measures. It is therefore to be particularly noticed, that the coal strata, which in most of the coal districts in England rest upon the upper transition or mountain limestone, in this part of Staffordshire rest upon the lower transition limestone. The remarkable fossil, the trilobite, called the Dudley fossil, occurs principally, if not entirely, in a stratum under the first limestone. There are shells in what are called the wild measures, but they are in a soft and decomposing state.

The lower transition limestone in England and Wales, is not a very extensive formation; it skirts the granite of Dartmoor, and part of the Malvern Hills; it extends in a narrow belt from

Wenlock, in Shropshire, to Caermarthen, in Wales, and is generally accompanied with soft greenish schistose strata, called dye earth, which contain numerous impressions of shells. A few patches of this limestone occur in various parts of the slate districts in Wales, and Cumberland. This part of the transition limestone series is chiefly remarkable for its organic remains; it is rarely metalliferous.

The upper transition or mountain limestone is, as I have before stated, the limestone to which the French geologists gave, *par excellence*, the name of *Calcaire de transition.* It is by many English geologists considered as a distinct formation from the lower, or what they call the true transition limestone; and it is said to be "separated from it by the important formation of the old red sandstone:" but the latter is only a variety of greywacke, and is acknowledged, even by those who make it a distinct formation, to graduate into greywacke, and to possess all the general characters of that rock, except that it is colored red. The old red sandstone contains, in some situations, beds of imperfect limestone, which may be said to connect the lower transition and mountain limestones into one formation, together with the associated beds of greywacke, red sandstone, and gritstone. In Denbighshire, and some parts of Craven in Yorkshire, a thick mass of conglomerate, consisting of sand and large water-worn boulders of the lower rock, separates the lowest beds of mountain limestone from the subjacent slate rocks.

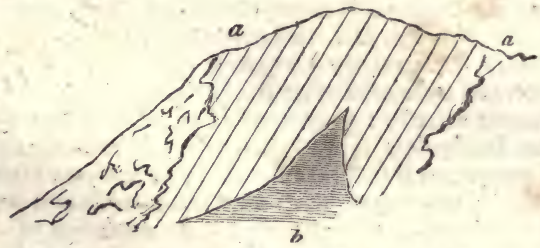
Mountain limestone is one of the most important calcareous rocks in England and Wales, both from its extent, the thickness and number of its beds, the quantity and variety of its organic remains, and its richness in metallic ores, particularly of lead. In Derbyshire, where the different beds of limestone have been pierced through by the miners, the average thickness of the three uppermost is about 160 yards; the beds are separated by beds of trap or basalt, resembling ancient lavas. The lowest limestone has not been pierced through. In the northern part of Yorkshire, and in Westmoreland and Cumberland, the beds of mountain limestone alternate with beds of greywacke slate, and of coarse sandstone. In North Wales, and in Somersetshire, mountain limestone forms entire mountain masses, of vast thickness, distinctly stratified; the strata often varying in color, and sometimes in the nature of their organic remains.

The beds of mountain limestone in England and Wales vary much in color and quality. The color is most commonly light grey, but it is sometimes black and sometimes a reddish brown, or is variegated. The limestone is generally sufficiently hard to receive a high polish, and forms what is denominated marble of considerable beauty. The texture is more or less crystalline.—The prevailing characteristic organic fossils are encrinites and

madrepores. The upper beds of mountain limestone in Derbyshire appear to be almost entirely composed of encrinites. A bed of black limestone with madrepores occurs in Westmoreland; it is more rare in Derbyshire, but is found in the lower part of the mountain limestone in North Wales, and Shropshire, and also in Devonshire. It takes a beautiful polish, and is much used for chimney-pieces. The black color appears to be derived from bitumen, for it is injured by heat, and is expelled entirely by burning. Mountain limestone is generally a nearly pure carbonate of lime; but some beds, and even entire hills of this limestone, contain a large portion of magnesia, like the dolomite of the Alps. The mountain magnesian limestone of England is generally harder than the common limestone, and has frequently a reddish brown color. Breedon Hill, in Leicestershire, and Cloud's Hill, in its vicinity, are entirely composed of magnesian limestone; there are several beds of similar limestone which form low hills in the adjacent country: they may all be regarded as an extension of the Derbyshire mountain limestone, ranging southward towards Charnwood Forest, and terminating at Grace Dieu, where the limestone is nearly in contact with the granitic and porphyritic rocks. I say these may be regarded as an extension of the Derbyshire mountain limestone, though the continuity is partly concealed by a covering of the red marl, and by coal measures: the limestone contains the same characteristic fossils as the Derbyshire limestone, particularly encrinites (screw stones,) and the euomphalus; but these are not abundant. The strata of Breedon Hill and Cloud's Hill are much exposed, having been extensively quarried for lime during a long period; they rise southerly from 45° to 60°. When I visited these hills in 1811, I was forcibly struck with the appearance and elevation of the strata, and I was disposed to attribute their position to the disturbing force which had elevated the granitic range of Charnwood; but such opinions were at that time much discouraged by English geologists. I visited these quarries again in 1830, after having repeatedly observed similar effects produced in the proximity of granite, and I was confirmed in my former views.

The theory of Von Buch respecting the conversion of common limestone into magnesian limestone by the proximity to porphyry, (see Chap. XI,) may be considered as deriving some support from the near approach of this magnesian limestone to the porphyry and porphyritic sienite of Charnwood. I shall refer to the subject elsewhere. The reason for entering more into detail, respecting the magnesian limestone of Breedon and Cloud's Hill than may appear consistent with an introductory work, is, that the strata of the latter hill present an anomalous appearance, which I have not observed elsewhere, and which is connected with the inquiry respecting the character of stratified rocks. At Cloud's Hill, the

face of the rock which is worked, rises to the height of about 300 feet. The stratification is most distinctly marked by regular strata seams, or partings, which show the elevation of the strata to be about 60°. In the midst of these strata there are masses in which all traces of stratification are obliterated; these masses are not separated by any partings or divisions whatever from the strata which surround them; the masses and limestone strata are precisely of the same quality, and similar in appearance. The masses are more difficult to work because they have no regular partings; these masses are on this account called, by the quarrymen, knobs. The annexed cut represents one of these unstratified knobs.



a a, strata of limestone; *b*, an unstratified knob of limestone.

Instances of unstratified beds, and masses of one kind of rock interposed between regular strata of another kind, are not uncommon; and in the midst of primary rocks, divided by regular cleavages, parts may frequently be seen, in which the cleavages or divisions are obliterated; but, in both these cases, the cause of this obliteration may be found in igneous fusion, combined with refrigeration. If the unstratified masses at Cloud's Hill owe their form to the action of heat, it is difficult, if not impossible to conceive, how this heat could have changed internal portions of the limestone, without affecting the surrounding strata. In Devonshire, and elsewhere, hills of mountain limestone may be seen, in which the stratification of the entire mass is obliterated or nearly so; but there can be no difficulty in this case,—indeed, it may be said that we do not know that the limestone was ever stratified, though the probabilities are greatly in favor of its having been so.

Remarkable sudden changes may be sometimes observed in the quality of the same beds of mountain limestone. At Llanymynah, in Shropshire, a hill composed of this limestone, the quality of the limestone on one side of the hill is considered by the limeburners of the very best kind; while, at a little distance, the same strata are so impure, from an intermixture with sand and clay, that they cannot be used with advantage. But what is more remarkable, I have seen, in this hill, a stratum of the best

limestone, lying regularly between other strata, suddenly terminate, and a whitish calcareous marl occupy its place, preserving the same degree of thickness, and the same direction. As these strata contain marine organic remains, and were deposited at the bottom of the ocean, we may suppose that a submarine current had prevented the limestone from extending further, and supplied its place by a deposition of clay, before the stratum above was deposited. In the former case, where the strata of good limestone become in some parts calcareous and impure, we may suppose that submarine currents, carrying away particles of sand, had intermixed them with the calcareous depositions in one part, but not in another. Indeed, this sudden change in the quality of the limestone is so common in part of North Wales, that the workmen have given to it the expressive name of *Balkstone.* When I was first informed of the balkstone, and saw that it impeded the operations of the quarrymen, I expected to have found a dyke of basalt, and was surprised to observe a mass of stratified limestone, of an impure quality, cutting through the best limestone like a thick wall, and left standing, the good limestone being worked away on each side of it. This wall of limestone was of a darker color than the rest; it contained the remains of encrinites. It is owing, I conceive, to the irregularities in the deposition of the strata, from causes attending their original formation, that soft and irregular beds or masses of clay occur in mountain limestone, which have subsequently been washed out by subterranean currents of water, and formed excavations and caverns of considerable magnitude. Many instances might be cited of large streams, and even rivers, engulfed in mountain limestone, and rising again at the distance of several miles. In the northern counties these openings are called Swallow Holes. Mr. Farey has enumerated twenty-eight swallow holes in the mountain limestone of Derbyshire.

It is in the lower beds of mountain limestone that enormous natural caverns frequently occur: such are the well known cavern near Castleton, and Pool's Hole, near Buxton, in Derbyshire, and Yordas Cave, under Whernside, in Craven. Gordal Scar and Weathercote Cove, in the same district, cannot properly be called caverns, as they are open to the day; but the latter was probably once a cavern, of which the roof has fallen in. In all these caverns, and others that I have observed in this limestone, there is a stream of running water, which is more or less copious in rainy or dry seasons. I am inclined to believe that the caverns have been formed by the agency of water percolating through natural fissures, and in the lapse of ages excavating the softer or more broken parts of the rock. The prodigious force with which these subterranean streams rush through the openings of some of these caverns, after continued rains, suggests the probability of this mode of formation. The whole of that enormous mass of lime-

stone in Craven, from Ingleborough and Whernside to Gordal, is intersected by perpendicular fissures, which are narrow at the top, and become wider as they descend, through which the water may be heard to run at a vast depth below. These unseen but ever active streams are slowly but progressively wearing down the internal parts of these calcareous mountains, and depositing them in the sea.

The mountain limestone of Derbyshire demands particular attention from the interesting geological phenomena which it presents; though it has been much visited and frequently described, I believe the accounts hitherto given have been in some respects erroneous. I revisited the country round Matlock soon after my return from the Continent, and was then convinced that the structure of the calcareous mountains had been mistaken; but the state of my health did not permit me to pursue the inquiry. Since the publication of the third edition of this work, I have again examined this part of the country carefully, and shall briefly state the result of my observations. Mr. Whitehurst has the merit of being the first observer who discovered some of the leading features of the geology of this district: he boldly pronounced that the beds of trap and amygdaloid, provincially called *Toadstone*, which are interposed in the limestone, were volcanic, or, at least, had an igneous origin. This opinion was much opposed at the time; it is now confirmed by such a weight of evidence, as to leave little doubt respecting its correctness (see Chap. X,) though the facts and arguments by which Mr. Whitehurst's views were then supported were in some respects fallacious.

Mr. Farey who followed Mr. Whitehurst, adopted the same views of the general structure of the country, though his opinions respecting the formation of the toadstone were entirely different; he considered it to be an aqueous deposition, forming regular strata, like those of sandstone in the coal measures.

Mr. Whitehurst and Mr. Farey describe three beds of toadstone, and four of limestone, in a descending series.

1. The first limestone 150 feet, with much white chert.
2. The first toadstone 48 feet, vesicular and amygdaloidal.
3. The second limestone 150 feet, contains beds of magnesian limestone.
4. The second toadstone 128 feet, more compact than the first toadstone.
5. The third limestone 180 feet, contains black madrepore beds.*

---

* 6. The third toadstone 66 feet, uncertain.

7. The fourth limestone not pierced through, uncertain.

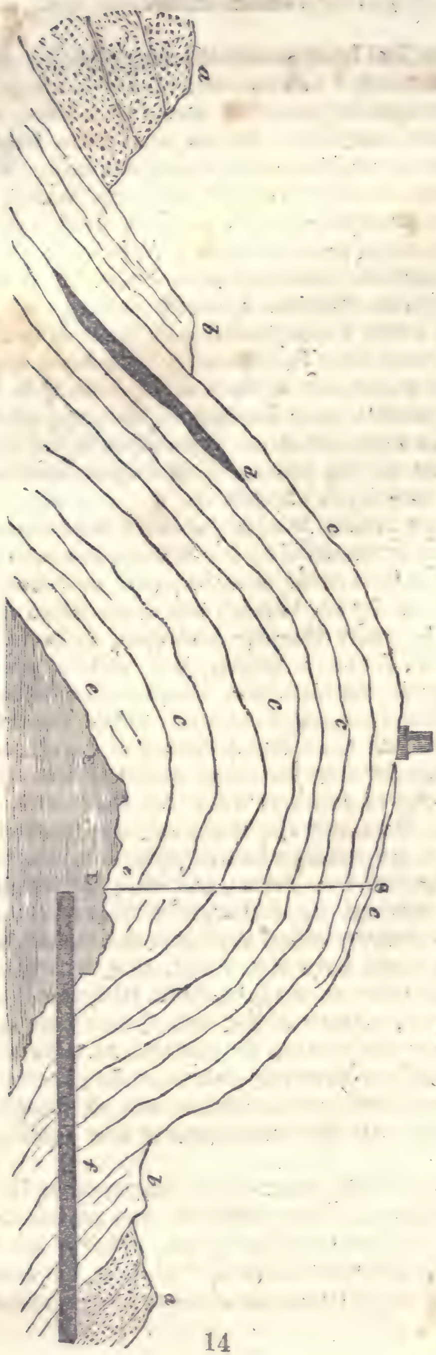
These beds, though mentioned by Farey and Whitehurst I regard as doubtful. If there be no regular third toadstone, the third limestone is the upper part of what they call the fourth limestone.

This may be an approximation to the thickness of the five upper beds near Matlock Bath, but is by no means an accurate statement of the succession and thickness of the beds, in other parts of the county. It may be proper to remark, also, that the limestone is distinctly stratified, and the strata of limestone are often divided by strata of clay, provincially called *way-boards*, and also by strata or rather seams of siliceous stone called chert, resembling flint, but less splintery in the fracture, and fusible; which latter property is doubtless owing to an admixture of calcareous earth. These strata of chert occur most frequently in the upper limestones: they contain, like the limestones, remains of shells, and encrinites. As loose blocks of chert with encrinites are sometimes ploughed up in the fields, Mr. Farey supposed that these blocks have been converted from limestone into chert by some unknown process,—an opinion for which there is not the slightest foundation. The chert blocks are the remains of hard strata, which have resisted decomposition or destruction, in the same manner as nodules of flint in the upper chalk. Large bivalve shells (*productus*) are found both in the limestone and chert. The thick beds of toadstone that divide the upper from the lower limestones, were supposed by Mr. Whitehurst to have been protruded between them in a state of fusion: this opinion will be examined subsequently. Admitting its truth, it would sufficiently account for the great irregularity in the thickness and succession of these beds, which is known to prevail throughout the Peak of Derbyshire. All the miners that I have examined on the subject, agree that the warm springs which abound in the vicinity of Matlock, rise from under the second toadstone, and that when this bed is first pierced through, the water has often a higher temperature than the Matlock Bath water, but its heat is reduced by admixture with cool springs in the upper beds.

I have now to observe that the descending series of limestone and toadstone, from No. 1 to No. 5, or the third limestone, may all be found in the vicinity of Matlock, and many other parts of the mining district; but the beds of toadstone are of very variable and uncertain thickness. With respect to the third toadstone, its occurrence as a regular bed is extremely doubtful. In some situations there are masses of toadstone intervening in the third limestone, which is of vast thickness; but these beds of toadstone are generally extremely irregular: where they occur, they of course divide the third limestone into two beds. The irregularity of these beds of toadstone, and the disturbance of the regular strata which they have caused, compelled Mr. Farey to call them *chance beds*, to avoid the admission of their igneous origin. In the same manner he explained the protrusion of the granitic range of rocks in Charnwood Forest: he described them as *chance beds in the red marl.* It was surely an extraordinary

chance, which produced rocks that extend under every other rock formation in the midland counties of England. There are, however, circumstances attending the stratification of the mountain limestone of Derbyshire, that have not been noticed by any of the authors I am acquainted with, who have described this country. There are evident indications of an upheaving force acting on several parts, and bending the strata into arches, the segments of large curves, as represented Plate II, fig. 1, *x*, *x*, *y*, and fig. 6, in the same plate. These curves are sometimes complete in the same hill; but frequently their continuity is broken. The strata of Matlock high Tor have been described by former writers as plane, and when seen in the face of the rock they appear to be nearly so, but they are in reality curved, as shown Plate 1, fig. 6. They enfold the back part of the hill, and are continued into the opposite hill, Masson, which they also enfold. The continuity of the strata is broken by the vale of the Derwent, which makes their true form more difficult to trace; but the arched stratification of the lower part of the same beds is distinctly displayed westward, and may be seen from the road near Matlock toll bar, where a section is made by the Derwent.

A very remarkable instance of the arched stratification, completely formed in one situation, may be seen four miles east of Matlock, in the isolated mountain called Crich Cliff, which rises about 900 feet above the Derwent. The strata rise all round, and enfold it, forming nearly spherical segments, as represented in the annexed cut. This section through the hill, represents the arrangement of the beds of limestone which dip all round the hill *c c c*, but are somewhat flattened at the top; the shale and gritstone surrounding the lower part of the hill are represented *a*, *b*. The true structure of the hill has been discovered by recent mining operations; several valuable metallic veins have been explored in it, and a gallery has been driven into it, as represented at *f*. It is obvious that this arched stucture can only be formed by protrusion; whereas the elevation or inclination of plane strata may have been produced by subsidence. Now, when we consider their near proximity to beds of toadstone of igneous formation, we can have little difficulty in assigning a cause for this protrusion; but, fortunately, we are not here obliged to have recourse to conjecture: in driving the gallery towards the centre of the hill, a mass of toadstone was met with (*e e*,) which was not cut through when I visited the place in 1830. The same toadstone was found by sinking a shaft upon it as represented in the cut at s. In this instance we have the effects of protrusion, and the cause, displayed in the same hill. It is true, the black compact toadstone had not been reached in 1830, but a great mass of indurated green earth, which always accompanies it, and is regarded by the miners as toadstone, and is called by



14

the same name, had been penetrated many yards. It was so hard as to require blasting. On one side of this hill is what is called a pipe vein, or opening between the strata, filled with metallic ore. This is represented in the cut at *d;* the workings in this vein have been continued nearly round the hill. There are also numerous cracks or veins rich in lead ore, which intersect the limestone at the bottom of the hill. Near the top of the hill there are quarries worked, which display the strata rising towards the summit on each side. Having shown that the mountain limestone of Derbyshire assumes, in many parts, the arched stratification, it may easily be conceived how persons, not aware of the circumstance, may have fallen into great mistakes in attempting to describe the succession of beds along a certain line; for the same beds, if arched, may rise near the surface, or above it, repeatedly, in the same country. (See Plate I, fig. 2.)

Other effects of the proximity of trap or toadstone on limestone, will be noticed in Chapter X.

I cannot omit, before leaving the mountain limestone of Derbyshire, to cite an instance of the influence which erroneous observations, combined with false theories, may have in retarding the progress of geology. Some years since, when it was the prevailing desire of many English geologists to make the different rocks agree with Werner's arrangement, and they were perplexed how to dispose of the mountain limestone—whether to place it in the transition class, or what were called the flœtz rocks, (or flat rocks,) in which class were included all the secondary strata—an eminent chemist from the north country, who affected a profound knowledge of geology, went into Derbyshire to decide the question, and, observing the strata opposite Matlock Bath to appear horizontal, he published an oracular opinion, that the limestone of Derbyshire was flœtz; and this opinion continued for some time to mislead the followers of Werner in this country. Now, had this observer taken the pains to obtain a true section of the strata, he might have discovered, that instead of being flat, they were inclined at an angle of 30 or 40 degrees. (See Plate I, fig. 6.) The strata, seen in the line of bearing, do appear horizontal, whereas the section in the line of dip shows their true elevation. Nothing, however, can be more puerile, than to form a classification of rocks on a circumstance so variable as the position of the beds; and the name flœtz is now banished from geology.

The upper transition or mountain limestone in England is particularly metalliferous: the principal ores are those of lead and zinc; they occur commonly in veins. Nearly all the lead obtained from the English mines is found in the mountain limestone. Ores of copper sometimes occur in this limestone.

Many of the fossil organic remains, both in the upper and lower transition rocks, are of genera that are not found in the secondary limestones. Some of the upper beds seem almost entirely composed of encrinites: madrepores and corallites occur abundantly in the middle part of this formation.

Quartz Rock.—Rocks composed entirely of crystalline grains of quartz, sometimes occur among primary and transition mountains. Certain causes appear to have operated locally, and separated the quartz and felspar of granite into masses of considerable size. The quartz rock in the county of Wicklow, I observed to be formed of what is called *greasy quartz*, similar to that in numerous veins in the mica slate, near its junction with granite in the adjacent mountains, and is probably contemporaneous with the veins. According to Dr. MacCulloch, the quartz rock in many parts of the Highlands, presents evident indications of being composed of fragments and rounded pieces again united, and is, in fact, a quartzose greywacke or grit. Part of the Lickey Hill, near Bromsgrove, is composed of granular quartz ; and similar beds occur near the village of Hartshill, in Warwickshire, between Atherstone and Nuneaton. Quartz rock, as distinguished from quartzose gritstone, is an inconsiderable formation, and may with more propriety be referred to the transition, than to the primary class.

Jasper.—This mineral is of rare occurrence as a constituent part of beds, or of mountain masses ; it differs little from a siliceous flinty slate, but is generally colored red, brown, or yellow, and is opaque. It contains a large portion of the oxide of iron in its composition. The beds of shale in coal mines that have taken fire, are sometimes converted into a substance in every respect resembling jasper. There are beds of jasper of considerable magnitude in some parts of the Apennines, covered by rocks of serpentine. In some situations, beds of slaty jasper alternate with slate, to which rock they appear to bear the same relation as flinty slate. Lydian stone, which is a black siliceous flint slate, is by some geologists called black jasper. The only bed of jasper that I have seen among the English rocks, occurs associated with beds of manganese ore, at Dodscombleigh, in Devonshire. Jasper sometimes occurs in veins, and forms nodules in basaltic rocks.

Hornblende Rock and *Greenstone.*—Hornblende and hornblende slate have been described as associated with primary rocks: they also occur in the lower transition rocks. Transition hornblende presents no variety of character, by which it can be distinguished from primary. Greenstone, composed of felspar and hornblende, in which the felspar is white, and sienitic greenstone, in which the felspar is red, sometimes occur in beds among transition rocks, particularly of slate.

Unconformable Transition Rocks.—Hornblende and hornblende slate, together with sienitic greenstone, and clinkstone, most frequently occur among transition rocks in an unconformable position, or form overlying masses: these properly belong to the class of trap rocks, and will be described in Chapter X. Many of these rocks appear identical with rocks of undisputed igneous origin; but in some situations, they graduate into rocks of the transition series, which appear to be sedimentary depositions: hence we are led to the conclusion, that subterranean heat has acted with different degrees of intensity on beds already formed, and has partially converted them into rocks resembling those of igneous formation. The two mighty agents, fire and water, appear, also, to have been in simultaneous operation, and have given a mixed or doubtful character to the rocks in many transition districts.

It may be useful to take a summary review of the different features presented by the transition districts of Cumberland, Westmoreland, and Yorkshire, in the north; and of Shropshire and North Wales in the middle districts, and of Devonshire in the south. Each of these districts presents considerable diversity of character, and also affords proofs of the mighty convulsions that agitated our planet, during considerable periods of the transition age. By these convulsions, many of the lower rocks were broken down into fragments, forming beds of conglomerate, and various compound sedimentary strata. In Cumberland and Westmoreland, rocks of an igneous character occur in vast beds, intermixed with slate and other sedimentary rocks, and in many instances appear for a certain space associated with them conformably. Twenty three years since, when I examined various parts of these districts, these appearances presented perplexing difficulties to my mind, as they have since done to other geologists. It was not then admitted, that aqueous and igneous epochs of formation could be synchronous. In many parts of Craven, in Yorkshire, the mountain limestone is only separated from the greywacke and slate, by beds of coarse conglomerate, which appear frequently to supply the place of the old red sandstone, and other transition beds.

In Devonshire, the most southern of the transition districts in England, the series consist principally of slate rocks and greywacke, with some beds of limestone. It has, however, been recently ascertained by Messrs. Murchison and Sedgwick, that an extensive surface in this county is covered by the great coal formation, once probably connected with that on the north side of the Bristol channel; but in Devonshire, the strata are more indurated, and the coal occurs in the state of hard coal, or Culm. The vegetable fossils are similar to those in the coal basin of South Wales.

In Shropshire, Radnorshire, and the adjacent Welsh counties, a series of sedimentary beds are found in the transition series, of which no trace has been noticed in the northern and southern transition districts.

The transition rocks of Shropshire and the adjacent Welsh counties, have been recently investigated by Mr. Murchison, a full and detailed account of which, by that gentleman, is soon expected to appear.

So far back as the year 1811, when engaged in a mineralogical examination of a part of Radnorshire, for a landed proprietor, who entertained the fallacious expectation of possessing valuable beds of coal on his estates, I was much surprised to observe the great extent and thickness of beds, which appeared to belong to what the Wernerian geologists denominated the greywacke formation, but in which were some imperfect traces of coal strata. In the first edition of this work, published in 1813, page 90, I stated, "that in one of the mountains near New Radnor, I had ascended a ravine, which displayed a succession of beds, intermediate between greywacke slate and sandstone, of at least 1300 feet in thickness." Between New Radnor and Ludlow, I also observed a vast succession of similar beds. That part of Wales was then a terra incognita to English geologists; and I had no opportunity of investigating that district afterwards, nor did it attract particular attention for twenty years, until Mr. Murchison undertook to examine it, and to trace the succession of the beds, and the various interesting phenomena which they present. To this series, comprising the middle and lower beds of transition rocks, he has given the name of *Silurian.* The order in which they succeed each other, ascending from the subjacent slate rocks, is as follows:—

Flagstones, consisting of schist, with trilobites, sandy slate, calcareous flags, and sandstone, to which is given the name of *Landeilo flags* and *Caradock sandstones.* They occur in Radnorshire and Caermarthenshire, and at Caer Caradock in Shropshire. The Caradock sandstones consist of micaceous sandstone, shelly limestones, and sandy limestones. To these beds, in the aggregate, Mr. Murchison assigns a thickness of several thousand feet.

Wenlock and Dudley Limestone and Shale.—These compose what English geologists formerly considered as *transition limestone par excellence*, abounding in trilobites and corallines. Their total thickness is estimated at 1800 feet.

Ludlow Rocks, consisting of dark calcined flags and shale, gray subcrystalline limestone, more or less argillaceous, and micaceous sandstone; the aggregate thickness 2000 feet.

The *Silurian beds* occur under the *Old Red Sandstone*, which consists of hard micaceous green sandstone, red and green lime-

stones, with argillaceous marl and beds of sandstone, with quartzose conglomerate, overlying thick-bedded sandstone. To these beds Mr. M. assigns the extraordinary thickness of 10,000 feet. Over them occur the mountain limestone beds already described.

The vast accumulation of beds which compose what is called the Silurian System, extend, but with considerable interruptions, from Caermarthenshire and Radnorshire on the west, to Dudley in Staffordshire: they are partly covered by coal measures and are broken by the intrusion of trap rocks, and by great faults and dislocations, which have thrown down or upraised part of the beds. From these interruptions and fractures it is perhaps difficult to obtain a correct estimate of the thickness of the different formations, and, what has been above stated, can, I conceive, be only regarded as distant approximations. The organic remains consist of marine shells and corallines, and trilobites, which indicate that the beds were deposited under an ancient ocean; but, in one part of the series, there occur beds under coal, containing what are regarded as undoubted fresh-water shells, which would prove that dry land, with lakes or rivers, had existed at that ancient epoch.

In the whole of the transition series of different countries, under the great coal formation, the prevailing organic remains are marine: no remains of vertebrated animals of a higher class than fish have yet been discovered; and no remains of terrestrial animals, that I know of, have yet been discovered in transition rocks, below the coal formation. Indeed, the evident contortions and disturbances of many of the transition rocks, and the intermixture of conglomerate and igneous rocks, indicate the extensive convulsions that must have agitated the surface of our planet at that ancient epoch; convulsions that retarded the development of organic life, and may also have obliterated all traces of animal existence, in situations where certain species flourished abundantly.

During these long ages of disturbance, there were, however, intervals of repose, in which the atmosphere and the ocean were serene and transparent. Dr. Buckland, with singular acuteness and felicity, has borrowed the eyes of the fossil trilobite, to examine the actual condition of the globe when that animal flourished. The trilobite, it has been before stated, is one of the most ancient inhabitants of our planet. It is an articulated aquatic animal, preserved in great perfection in transition rocks in England, and in various parts of the world. The eyes of the trilobite, like those of several insects and crustaceous animals, are constructed of a series of small lenses, evidently adapted to distinct vision, and requiring a tranquil and transparent medium for the performance of the visual functions, or, in other words, a clear and tranquil state of the water and atmosphere was necessary, to enable the animal to use its eyes with advantage. See the ad-

mirable chapter on the Eyes of the Trilobite, by Dr. Buckland. *B. T. vol.* 1, *page* 396.

In Chapter II. we have given a summary statement of the vegetation of the transition epoch. In the upper series, comprising the great coal formation in very different degrees of latitude, we meet with abundance of fossil remains of large plants, analogous to what now grow in tropical climates. From hence we are led to infer, that our globe possessed generally a very high degree of temperature at the latter part of the transition epoch. With respect to the temperature of the earlier periods, we are less certain; for the vegetable remains in the lower transition rocks are chiefly marine, and the submarine rocks, on which the fuci grew, might derive a local temperature from adjacent igneous rocks.

The rare occurrence of remains of terrestrial plants and animals, in the earlier transition rocks, would indicate, that the surface of our planet was not then covered with extensive islands or tracts of permanently dry land: but that it was progressively advancing to a condition suited to support higher forms of vegetable and animal organization. Of the lower classes of animals, we find abundant remains in the transition series of the middle period. These remains are, chiefly,

1. *Radiated:* corallines, madrepores, and encrinites.
2. *Articulated:* the trilobite, and a few small crustaceous animals, confined to particular beds.
3. *Molluscous:* certain species of bivalves, and the nautilus, with a few species of univalves.
4. *Vertebrated:* certain species of fish, not hitherto found in more recent strata; but neither remains of reptiles, birds, nor mammalia, have yet been discovered.

It was till recently believed, that the teeth of large reptiles, analogous to crocodiles, had been found in fresh-water limestone, below the coal formation, at Burdie House, near Edinburgh; but M. Agassiz has ascertained, that these teeth belonged to distinct genera of fish, approaching to saurians in the structure of their teeth. To these he has given the name of Sauroid fishes.

In the organic remains of the earliest transition rocks, we appear to trace the first manifestations on our own planet, of creative power displayed in the animal and vegetable kingdoms. This is strongly confirmed, by the similarity of these early remains in the transition rocks of distant regions, and still farther, by observing the progressive advancement to higher forms of organic life, as we ascend through the secondary into the tertiary state, indicating a progressive improvement in the condition of the globe, until it became suited to the residence of man, and the highest orders of terrestrial animals.

Some geologists would discard the use of the term *Transition Rocks;* a term which has been generally employed ever since geology became a science. Such a change would introduce much unnecessary difficulty and confusion into geological descriptions, and retard the progress of knowledge. The *Silurian system*, for instance, is named after a tribe of ancient Britons, and the members of which it is composed, are named after obscure localities in England. These names, if unconnected with the *Transition series*, convey no meaning whatever to the foreign geologist, but if it be stated that the Silurian system comprises a series of *Transition beds* below the Old Red Sandstone, the true position of these beds will be every where understood.

CHAPTER VIII.

ON THE LOWER OR GREAT COAL FORMATION.

The Geological Position and Structure of Coal Districts, called Coal-Fields.—Dislocation and Disturbances of Coal Strata by Faults and Dykes.—Mineral Coal, Anthracite, Plumbago, Wood Coal or Lignite.—Ironstone accompanying Coal Strata.—On Carbon as an original Constituent Part of the Globe.—On the Origin of Coal Strata, and their Deposition in Fresh-Water Lakes or Marshes.—Numerous Repetitions of the same series of Beds in the same Coal-Field.—Precautions necessary in the establishment of Iron Furnaces.—On the Mode of searching for Coal.—Hints to landed Proprietors on the Probability of finding Coal in Districts where it has not yet been discovered.—On the Formation of Coal Beds in Fresh-Water Lakes.—On the Conversion of Vegetable Matter into Coal.—Imperfect Coal Formations.—Salt Springs in Coal Strata.—Coal Mines in France and North America.—Observations on the Consumption of Coal in England, and the Period when the Coal Beds will be exhausted.—Additional Remarks on the same Subject.—Section of the Coal Strata at Ashby Wolds.

In the lower transition rocks covering the primary, described in the preceding chapter, we very rarely discover any remains of vegetables, either terrestrial or marine. Carbon, which is the principal constituent element of all plants, is seldom found as a mineral substance in these rocks: for, with a few exceptions, the vestiges of organic forms which they contain, are of marine animals. Hence we are led to infer, that there were but few islands, or tracts of dry land, rising above the ancient ocean, in which these marine calcareous beds were formed or deposited. The attention of the geological student is now required to contemplate a most important and extensive change in the condition of the globe,—at least, of that part of it which forms the subject of the present chapter. Over the marine rock formations before described, we find a series of strata, two thousand feet or more in aggregate depth, in which remains of marine animals are extremely rare, but which contain, almost exclusively, the remains of terrestrial plants, or such as have grown either on dry land or in marshes. Carbon, in the form of coal, constitutes also numerous beds in the series, varying in thickness from a few inches to thirty feet or more, and alternating with beds of sandstone, indurated clay, and shale or schistose clay. The remains of vegetables are distributed in greater or lesser abundance throughout the whole series, which, taken together, are called by miners in the north, *coal measures.* The coal strata were, doubtless, deposited in the vicinity of extensive tracts of dry land, containing rivers, marshes, and fresh-water lakes: the marine beds which form the foundation of the series of coal strata, and also surround them, must, therefore, have been raised from the bottom of the ancient deep, before the vast accumulation of vegetable matter could

be formed. To whatever cause we attribute this change in the condition of the globe, it appears to have been attended with another remarkable effect; after this period, metallic veins have been rarely formed, for they seldom rise into the coal strata. The vegetable remains that are in the coal strata, appear principally to belong to plants analogous to those that abound chiefly in tropical climates, as will be subsequently noticed. In no country have coal measures been more extensively worked than in England, or the relations of the strata to the rocks above or below them been more fully examined.

Every coal district has its peculiar series of strata, unconnected with any other, though there is a general resemblance in the nature of the different beds. A district, with its peculiar series of strata, is called a coal-field. The foundation rock on which the coal-fields of Derbyshire, Northumberland, Durham, Shropshire, and North and South Wales, immediately rest, is the mountain or upper transition limestone, described in Chapter VII.* In Nottinghamshire, Yorkshire, and Lancashire, the foundation rock has not been sunk to, but we have every reason to believe that it is formed by a continuation of the same limestone, though this is by no means essential to a coal-field. In some parts of France, I have observed the coal strata resting upon granite; being only separated from it by a thick bed of conglomerate. A general view of the arrangement of the Derbyshire coal-field, may be taken as affording a type of the whole English coal-fields, with certain exceptions, which will be noticed.

The thick beds of mountain limestone (see Chap. VII,) which form entire mountains, decline in height towards the eastern side of the country, and are discovered by the coal measures. The lowest bed of these measures, or, to speak more correctly, the bed which separates the coal measures from the limestone, partakes of a mixed character, varying from soft argillaceous shale to hard sandstone; the prevailing color is a dark reddish or blackish brown. This bed has been called *limestone shale*: its total thickness varies from five to six hundred feet, but in some situations is much less.

The harder strata of which this great bed is composed, are separated by soft beds that easily disintegrate and fall down; they form the exposed face of Mam Tor, or the Shivering Mountain, near Castleton. The peculiar circumstance which renders this bed remarkable is, that though it contains chiefly vegetable remains, it contains also occasional patches, or limited strata of dark bituminous limestone, with beds and nodules of ironstone,

---

* At Dudley, in Staffordshire, the coal-field rests on the lower transition limestone, distinguished by its abundant remains of trilobites, hence formerly called the Dudley fossil.

and thin seams of coal, which, however interesting they may be to the geological enquirer, are too inconsiderable to be worked.

The next large bed above, is in some situations from three to four hundred feet in thickness; it is chiefly composed of strata of hard siliceous sandstone, which is in some places coarse, containing angular fragments of quartz; in other parts, it is a fine grained and very durable stone. Some of the strata of this bed were formerly worked for millstones; from which circumstance it received the name of *Millstone Grit.** It contains, as far as I have examined, the remains of vegetables exclusively, but no beds of workable coal occur in it. Where the strata crop or basset out, this rock forms abrupt and picturesque cliffs. Above the grit, are laid the regular series of coal measures or strata, comprising sandstone of various qualities, indurated clay called *clunch*, ironstone, softer argillaceous beds called *bind*, and schistose argillaceous beds, called shale. There are also two argillaceous strata containing numerous shells of fresh-water muscles, and hence called *Muscle bind.*

A gentleman extensively engaged in the working of coal mines in this district, had a measure taken of the thickness of the different beds, which he sent me, and was published in the first edition of this work; from which "it appears, that the total depth taken on the level line of the measure of the whole Derbyshire strata, including part of Nottinghamshire, is thirteen hundred and ten yards, in which are thirty different beds of coal, varying in thickness from six inches to eleven feet, making the total thickness of coal twenty six yards; of course the above estimate can be only regarded as an approximation to truth, since the thickness of the strata was taken upon a level line, and not perpendicular to the line of their inclination or dip." Making an allowance for excess in the above measurement, the true thickness of the strata may fairly be estimated at about two thousand five hundred feet.

What is particularly deserving of notice in the bed of limestone shale before mentioned, below the coal measures, and above the mountain limestone, is, that this bed presents a transition from marine calcareous strata with animal remains, to fresh-water strata with terrestrial vegetables; as both occur in different parts of the bed, it would imply, that the subjacent limestone had been gradually but unequally raised above the sea, and during its elevation some parts remained immersed in the ocean, while other parts were covered with vegetable depositions. In the western side of Durham and Northumberland, the alternations of coal of in-

* The relations of the limestone shale and the millstone grit, to the mountain limestone on the west, and the coal strata on the east, is represented Plate 4, fig. 1.

ferior quality with beds of mountain limestone, are more distinct, and the transition from marine to fresh-water formations are on a larger scale: both prove that the elevation of the beds above the sea was effected by the operation of an elevating force acting slowly, or at distant intervals. On the western side of the Yorkshire coal-field, near Halifax, ammonites, and other marine shells, are found in the lower strata, proving an occasional irruption of the sea into the lake or basin in which the coal is deposited.

Coal-fields, as before stated, are of limited extent, and the strata frequently dip to a common centre, being often arranged in basin-shaped concavities, which appear to have been originally detached lakes, that were gradually filled by repeated depositions of carbonaceous and mineral matter. In some of the larger coal-fields, the original form of the lake cannot be traced; but in the smaller ones it is distinctly preserved.

The different strata under a bed of coal are frequently similar to the strata over it; and the same series is again repeated, in some mines several times, under different beds of coal, with a perfect similarity both in the succession and thickness of each. In some instances, a single bed of stone of vast thickness separates two beds of coal. In other instances, only a very thin stratum of shale or clay lies between coal beds.

Though numerous beds or seams of coal occur in one coal-field, very rarely more than three of these are worked. The thickness of the coal strata in the same coal-field, often varies from a few inches to several yards; but each stratum generally preserves nearly the same thickness throughout its whole extent. Instances to the contrary sometimes occur, in which the same bed will become narrower or wider, and sometimes be divided by a stratum of incombustible earthy matter, in different parts of its course. Few beds of coal are worked at a great depth, which are less than two feet in thickness. The stratum lying over a bed of coal is called its roof, and the stratum under it the floor. The facility of getting coal depends very much on the compactness of the stone which forms the roof, not only on account of the security from falling, but for keeping out the upper water, and preserving the pit in a dry state. The great expense incurred in supporting the roof when it is loose, frequently prevents a valuable bed of coal from being worked, or absorbs all the profit. In some situations, the roof is indurated clay, impregnated with bitumen and pyrites. When this falls down, and is intermixed with water and small coal at the bottom, it takes fire spontaneously; on which account the miners close up the space with common clay, where the coal has been worked, to prevent the access of air to the combustible matter. This kind of combustible clay is called *tow;* it is common in the Ashby-de-la-Zouch coal-field, and in Staffordshire. The floor or stratum on which

the coal lies, consists of clay in various degrees of induration, and is almost always of that kind which will resist the action of fire, called fire clay, suited for furnace bricks and crucibles.

It has been before observed, that coal strata are frequently bent in concavities, resembling a trough or basin, dipping down on one side of the field and rising on the other. In Plate IV, fig. 2, the section of a coal-field is represented, in which the coal strata C C C, D D are inclined in this manner, but partially dislocated by a fracture or fault at F. The extremities of the lowest stratum, C C, are several miles distant in some coal-fields; in others, not more than one mile.

In the great coal-field in South Wales, which is rather a long trough than a basin, the strata are arranged in this manner over an extent of nearly a hundred miles in length, and a variable breadth of from five to twenty miles. It is partly broken into by Caermarthen Bay; but it forms an extent of surface exceeding twelve hundred square miles. It contains twenty three beds of workable coal, which are said by Mr. Martin to make together ninety five feet in thickness of this valuable mineral: this will yield sixty four million tons of coal per square mile. The thickest bed of coal is nine feet; in some parts there are sixteen seams of ironstone. The strata of this vast coal-field are deeply cut through by valleys, and are much broken by faults, and the quality of the coal varies greatly in different parts of the field. About one third of the coal is stated to be culm, or stone coal; this occurs chiefly on the western side of the basin between the vale of Neath, in Glamorganshire, and Bride's Bay, in Pembrokeshire.

An important geological discovery has recently been made by Messrs. Sedgwick and Murchison: they have ascertained that the South Wales coal basin extends into Devonshire, and is separated only by the intervention of the British Channel. The coal strata of Devon represent the lower parts of the South Wales coal-field, forming, in fact, the southern side of the great coal basin. In Devonshire, part of this coal basin rests on granite: in South Wales, the foundation rocks of the whole coal series below the millstone grit and mountain limestone, are grauwacké. The coal is hard culm; it is not very abundant. The fossil vegetable remains are similar to those in the South Wales basin.

At the Clee Hills in Shropshire, the breadth of some of the coal-fields is not a mile. At Ashby Wolds, in Leicestershire, in the central part of the field at *e*, Plate IV, fig. 2, the main bed of coal is worked at the depth of two hundred and forty yards,* but by the bending and rise of the strata, the same bed comes to

* This was the depth of the mine in 1812; since that time a mine has been sunk to the depth of three hundred yards into the same bed.

the surface at b, about three miles distant. The depth of coal strata, from the inclination or bending of the strata, differs much in the same district, as will be evident from what has been stated, and from an inspection of the last mentioned figure. Some coal-fields extend in a waving form over a district.

On the eastern side of England, the strata generally decline, or, in the miner's language, dip, to the southeast point: on the western side, the strata are more frequently thrown into different and opposite directions, by what are called faults and dykes.

A fault is a break or intersection of strata, by which they are commonly raised or thrown down; so that in working a bed of coal, the miners come suddenly to its apparent termination. A dyke is a wall of mineral matter, cutting through the strata in a position nearly vertical. (See Plate IV, figs. 2 and 3.) The name *dyke*, is originally derived from our northern neighbors: it signifies a wall. The thickness of dykes varies from a few inches to twenty or thirty feet, and even yards. The dykes which intersect coal strata are frequently composed of indurated clay, or of basalt, and will be particularly described in the following chapter. In some coal-fields, the strata are raised or thrown down on one side of a dyke one hundred and fifty yards or more; and the miner, after penetrating through it, (see Plate IV, fig. 3,) instead of finding the same coal again, meets with beds of stone or clay on the other side at e: hence he is frequently at a loss how to proceed in searching for the coal which is thus cut off. If the stratum of stone e, be the same as any of the strata which were sunk through in making the pit or shaft $g\ g$, it proves that the bed of coal on the other side of the fault is thrown down, and he can determine the exact distance between that stratum, and the coal he is in search of. But if the stone is of a different kind to any which was above the coal he is working, he may be certain that the strata on the other side of the fault are thrown up, but to what distance can only be ascertained by trial, if the under strata have not been previously perforated. It frequently happens, however, that two or more strata of stone or shale, at different depths, are so similar in their quality and appearance, that it is impossible to distinguish them: in such cases it is necessary to perforate the stratum to ascertain its thickness, and examine the quality of the strata above or below it, by which its identity with any known stratum may generally be ascertained. The manner in which the strata are inclined towards the fault, will also determine whether they are thrown up or down, provided they are not shattered where they come in contact with it, which is frequently the case.* Each

* If the dyke make an acute angle with the upper surface of the strata, they are thrown up on that side; but if it make an obtuse angle, they are thrown down. See Plate IV, fig. 2, D; and fig. 3, *d*.

bed of coal in a coal-field has certain characters by which it may generally be known to be the same. Its thickness, and the quality of the roof and floor, with that of the upper and under strata, generally serve to identify it, though it may be much deeper in one place than another.

The dykes which intersect coal strata are generally impervious to water; and it not unfrequently happens, that where the strata decline to them, they hold up the water, and occasion springs at the surface, or keep the coal works on that side of the fault under water, when the coal works on the other side are dry. This will be better understood by referring to Plate IV, figs. 2 and 3, where the coal strata on the right hand decline or dip to the fault or dyke; and the water which passes through or between the strata will be stopped at the faults and damned up; in which case the coal beds to the right of the dyke will be under water, and those on the other side dry. Now, should a perforation be incautiously made through the dyke, all the water will be thrown upon the works on the left, that were before dry. Where the coal on each side of a fault belongs to different proprietors, a few strokes with a pickaxe may thus do incalculable mischief to those on the one side, and render great service to the other, by laying their pits dry.

The deepest coal mines in England are those in Northumberland and in the county of Durham, some of which are worked three hundred yards below the surface. The thickest bed of English coal of any considerable extent is the main coal in Staffordshire, which is thirty feet. The upper, lower, and middle parts of the bed differ in quality. Mr. Keir, who has written an interesting account of the mineralogy of the south of Staffordshire, says that thirteen different kinds of coal occur over each other in this bed; the uppermost, which is compact, serves as a roof in getting the under coal. At the Wood Mill-hill colliery in this county, the coal is said to be forty five feet thick; and three beds of coal, from three to four feet in thickness, have been found under it, since Mr. Keir's account was published. The first is only two yards under the thick coal. The main bed of coal in the Ashby-de-la-Zouch coal-field is thirteen feet thick; the upper and lower seams of this bed also vary in quality; a seam near the middle is so compact that it may serve as a good roof for the under coal. Few beds of coal in other parts of England or in Wales exceed from six to nine feet in thickness; but a difference in the quality may generally be observed in the upper, lower, and middle parts of the same bed.

A curious fact is stated by Mr. Keir respecting the main coal of Staffordshire. In one situation the upper part of the bed separates from the lower, and rises to the surface, or crops out. It is at first divided by indurated clay called bind or clunch; but as the distance becomes wider, the intervening stone grows harder, and will

strike fire with flint. Similar separations take place sometimes in the beds of coal in the mines of Northumberland and Durham. The largest known bed of coal in the West Riding of Yorkshire is near Barnsley: it is ten feet thick, and is supposed to be formed by the meeting of two or more seams, which soon separate again. The miners have not been able to trace the same bed in situations where it might have been found, had it preserved the same thickness, in other parts of its course.

Coal strata, beside the more common dislocations by faults, present remarkable contortions, which it would be difficult to explain, except by admitting a lateral force, which has compressed them into a zigzag form. To the same cause, or perhaps to a partial sinking of the earth, we may attribute the origin of what is called *faulty ground*, which frequently occurs in coal-fields. In this, no actual dyke appears to have been formed; but the beds of coal, with all the accompanying strata, are so broken and shattered, that no workings can be carried on, till the miner has got through them into regular strata. These broken parts of the strata, called *troubles* and *faulty ground*, occasion much more difficulty to the miner than common faults or dykes, and are sometimes of great breadth.

In some coal-fields one part of a stratum is inclined, and the other part vertical. A curious fact of this kind may be seen in a small coal-field near the town of Manchester.*

The position of coal strata in many coal-fields may be represented by a series of fresh-water muscle shells, decreasing in size, laid within each other, but separated by a thin paste of clay. If one side of the shell be raised, it will represent the general rise of the strata in that direction; and if the whole series be dislocated by partial cracks, raising one part a little and depressing the other, to represent faults in the coal, it will give a better idea of the coal-field than any description can convey. We are here to suppose that each shell represents a stratum of coal, and the partitions of clay the earthy strata by which they are separated. The outer shell represents the lowest bed of coal, which may be many miles in extent. Now, if a much larger shell be filled with sand, and the lowest shell be pressed into it, we may consider the large shell to represent limestone, and the sand gritstone; we shall then have a model of the coal strata in many parts of England, and their situation over the metalliferous lime, with the beds of sandstone by which they are separated from it.

From the inclination or bending of coal strata, they always rise near to the surface in some parts of their course, and would be visible if not covered by soil or gravel. In the banks of ra-

* I have given a short account of this coal-field in the second volume of the Transactions of the Geological Society.

vines formed by rivulets, or in accidental fractures on the sides of hills in a district, the nature of the strata, may often be determined, and should be ascertained, before any expense be incurred in boring or sinking for coal. When this is done, a proper station should be chosen, which requires great judgment; otherwise it is possible to bore or sink to great depths, and miss a bed of coal which exists very near the place; this will be evident from the inspection of the two stations, *a* and *b*, Plate IV, fig. 2: in the latter, it would be impossible to meet with the bed of coal, c, because the search is made beyond the line where it rises to the surface, or, in the miner's language, crops out. At *a*, coal would be found after sinking only a few yards.* In most situations, it is better to search for coal, as deep as can be done without expensive machinery, by sinking a well in preference to boring. By sinking, a decisive knowledge of the nature and thickness of the strata can be ascertained as far as you descend, which can only be imperfectly known by boring; for the latter mode is liable to great uncertainty of result, from bendings or slips of the strata. If, for instance, the borer be worked in the situation *a*, Plate IV, fig. 2, it will pass through a great depth of coal, which in reality may not be more than a few inches in thickness. Besides the uncertainty of the results, the grossest impositions are sometimes practiced to answer interested purposes, and induce proprietors to continue the search, where there is no reasonable probability of success.

Where coal strata come to the surface, they are generally in a soft decomposed state, and intermixed with earthy matter. They frequently present no appearance of coal, but the soil may be observed of a darker color. The real quality of the coal cannot be ascertained until it is found below, in its natural undecomposed state, lying between two regular strata of stone or indurated clay. In general it is observed, that the same bed improves in quality, as it sinks deeper into the earth. Coal strata are generally split or divisible into rhomboidal blocks, by vertical joints: these are called slines; the oblique shorter joints are called cutters.

From what will be stated in the subsequent chapters, it will appear that there is more than one third of England in which all search for valuable coal is useless: the knowledge of a negative fact becomes important, when it saves us from loss of time, expense, and disappointment.

Common coal is a mineral too well known to require a particular description. Mineralogists divide coal into two species,—Brown coal, and Black coal: the former, sometimes called wood coal, is chiefly found in tertiary shale or in alluvial ground. It

* In 1811, I saw, in Radnorshire, a fruitless search for coal of this kind; a bed of coal of a bad quality rose near the surface, and the attempts to obtain it were made beyond the outcrop of the bed.

contains, besides charcoal and bitumen, various vegetable principles, and the branches or trunks of trees partially decomposed, which mark the origin of this kind of coal.

Black coal, or *common coal*, is composed of charcoal, bitumen, and earthy matter. The latter forms the ashes which remain after combustion: these vary in proportion in different coals, from two to near twenty per cent. The proportion of bitumen varies from twenty to forty per cent., and the charcoal from forty to more than eighty per cent.

Mineralogists have enumerated many different kinds of black coal: several of these pass by gradation into each other in the same mine. The most important varieties, in an economical view, are the hard coal, like that of Staffordshire, and bituminous or caking coal, called in London sea coal.

Anthracite is a mineral approaching to the state of plumbago: it consists nearly of pure carbon, is extremely hard and difficult to ignite, and has often a semi-metallic lustre. It occurs in rocks which have generally been regarded as belonging to the transition class, but is sometimes found in small quantities in regular coal strata. The coal in the extensive coal formation of Pennsylvania, is called anthracite, because it emits but little smoke in burning, but is only a variety of common coal, containing but little bitumen.*

Coal strata are frequently accompanied by thin strata of ironstone. This stone has a dark brown or grey color: it has an earthy appearance and fracture, and is about three times heavier than an equal bulk of water. Some kinds have the specific gravity of 3.6. Though modern mineralogists call this mineral clay ironstone, after Werner, from its resemblance to argillaceous stones, on analysis it is found to contain but a very minute portion of alumine or pure clay, sometimes not more than two per cent. It is principally composed of iron combined with oxygen, carbonic acid, and water, and a small quantity of silex, and in some instances with calcareous earth. If it be of a good quality, it yields more than thirty per cent. of iron. In some of the beds of clay over coal, detached nodules of ironstone occur, which are also smelted for iron.

The vast extent and importance of our iron works are well known; but their establishment is of recent date. Formerly, our furnaces were on a diminutive scale, and wood or charcoal was the only fuel employed; but in the present cultivated state of the country, wood could not be procured in requisite quantity. The application of coal or coke to the smelting of iron is among the most useful of modern improvements; but it is only some

* The culm or stone coal in South Wales, which contains scarcely any bitumen, has recently received the name of anthracite: it is not, however, identical with the anthracite of mineralogists, found in primary rocks.

kinds of coal that are proper for the purpose. Inattention to this circumstance has frequently led landed proprietors to great unprofitable expense. Finding ironstone and coal in abundance upon their estates, they have constructed furnaces and other works at a considerable cost, and have discovered too late that the coal, however suitable for domestic or other uses, was unfit to make iron of a marketable quality. To make good iron from the best ironstone, it is necessary that the coal should be as free as possible from every substance with which sulphur is combined. It should possess the property of forming a hard coke or cinder; and if it have the quality of cementing or *caking*, it is the more valuable, as the small coal can then be used for the purpose of coking, which is frequently wasted where it does not possess this quality.

Different opinions have been formed respecting the origin of coal. In the primary and transition mountains, a particular species of coal occurs in small quantities, as before stated, which is extremely hard and splendent, and burns without smoke or flame, and is called anthracite: it resembles, and appears to pass into, the mineral called plumbago or graphite. Common coal, also, sometimes graduates into plumbago. Plumbago and anthracite are so completely mineralized, as to present no indications of a vegetable origin; but the slate, in which anthracite is imbedded, sometimes contains impressions of ferns, and the strata over common coal abound in vegetable impressions: the cortical part of the vegetable is frequently seen converted into mineral coal. It is not often that vegetable impressions are found in the coal itself; but some of the regular coal beds in the Dudley coal-field, of which I have specimens of considerable size and thickness, are composed of distinct layers of vegetables, converted into true mineral coal, and when separated, preserving the distinct cortical impressions of plants throughout the whole thickness of the coal. It is reasonable to believe, that all the coal beds in the same field are also formed of vegetable matter, though the impressions may be effaced. I have also a specimen of common coal from Derbyshire, with different cortical impressions.*

Granting that common coal is originally derived from the decomposition of vegetables, it may be fairly asked,—from whence did the vegetable tribes originally derive the carbon of which their solid parts are principally composed? Carbon either previously existed in nature, or trees and plants had the power of forming it from more simple elements. Neither of these opinions is improbable, nor are they at variance with each other. If carbon be a compound substance, of which hydrogen is a constituent part, it may be formed by the process of vegetation, or it may exist also

* "Mr. Hutton has ascertained that in all the three varieties of coal found near Newcastle, a vegetable structure may be discovered by the microscope, if the coal be cut in very thin slices."—*Buckland's B. T.* vol. i, p. 455.

in the mineral kingdom, independent of organic productions. That carbon is an original constituent elementary part of the globe, can scarcely be doubted, when we consider that, united with oxygen, it is an important constituent part of all limestone mountains, composing nearly one half, by weight, of their substance, or 44 of carbonic acid to 56 of lime. Now, the quantity of carbon, when separated from the oxygen, would be equal to one eighth of the whole mass of limestone; and, as all the ancient limestone formations were deposited under the ocean, we cannot suppose that this carbon was derived from the vegetable kingdom. Could the carbon be separated from the limestone in the great calcareous ranges of the Jura and the Alps, it would form a bed of pure carbon, nearly a thousand feet in thickness, through the vast extent of these mountains: and were we forced to admit that this carbon was derived from organic secretion, we should rather look to the animal than the vegetable kingdom for its origin; as no small portion of many calcareous mountains is composed of animal remains, and calcareous beds are forming in our present seas, of great extent and thickness, by the accumulation of shells and coral.

M. Adolphus Brongniart, in a recent work on vegetable fossils, has ingeniously suggested another origin for vegetable carbon. He admits, as I have done, that carbon is an original element in the composition of the globe and its atmosphere. He supposes that the atmosphere of the ancient world might contain more carbonic acid than at present. This would be highly favorable to the rapid growth of plants; and, in proportion as the plants absorbed the excess of carbonic acid, (fixed air,) they would render the atmosphere more pure, and fit it for the future respiration of animals.

Bitumen, which is composed of carbon and hydrogen, is known to exude from the lava of recent volcanoes; and the volcanic tufa in Auvergne, which covers a vast extent of surface, is almost every where intermixed with bitumen. In hot weather, I have seen it trickling out of the tufa in considerable quantities, resembling melted pitch. As the ancient volcanoes of that district broke out from beneath the granite, we may fairly infer, that the bitumen which abounds in the volcanic tufa, is as much a mineral substance as the sulphur which accompanies volcanic eruptions, or which is sublimed from the vapors of quiescent volcanoes.

Though the carbon that exists as a constituent part in some primary rocks may be derived from the mineral kingdom, there can scarcely remain a doubt, that wood coal and common coal are of vegetable origin.

Wood coal, or brown coal, is found in low situations, and appears to have been formed of heaps of trees buried by inundations under beds of clay, sand, or gravel. The woody parts have pro-

bably undergone a certain degree of vegetable fermentation, under the pressure of the incumbent earthy matter, by which they have been carbonized and consolidated. In some specimens of this coal, the vegetable fibre or grain is perceptible in one part, and the other part is reduced to coal. The vegetable principles which this coal contains, united with bitumen and charcoal, have been already stated. In black, or common coal, the vegetable extract and resin are destroyed, and the charcoal and bitumen alone remain; but wood coal and common coal bear in other respects too close a resemblance, to allow us to ascribe to them a different origin, though they were probably formed from different tribes in the vegetable kingdom, and under different circumstances.

Wood coal* is found in considerable quantities at Bovey Heathfield, near Exeter. Several beds of coal are separated by strata of clay and gravel: the lowest is seventeen feet thick, and rests on a bed of clay, under which is sand, resembling sea sand. The coal in contact with the clay has a brown color, and appears intermixed with earth. In other parts, the laminæ of the coal undulate, and resemble the roots of trees: in the middle of the lowest stratum, the coal is more compact, and is of a black color, and nearly as heavy as common coal.

A great repository of this kind of coal exists near Cologne: it extends for many leagues: it is fifty feet in thickness, and is covered with a bed of gravel from twelve to twenty feet deep. Trunks of trees deprived of their branches, are imbedded in this coal; which proves that they have been transported from a distance. Nuts, which are indigenous to Hindostan and China, and a fragrant resinous substance, are also found in it. A similar resinous substance occurs in the Bovey coal, and was also discovered with fossil wood, in cutting through Highgate Hill. Mr. Hatchett, by whom it was analyzed, has given it the name of retinasphaltum.

In wood coal, we may almost seize nature in the act of making coal, before the process is completed. These formations of coal are of far more recent date than that of common coal, though their origin must be referred to a former condition of the globe, when animals like those existing at present in tropical climates flourished in northern latitudes, as their remains sometimes occur in the wood coal of Europe.

The vegetable origin of common mineral coal appears to be established by its association with strata abounding in vegetable

---

* The description of wood coal ought to be placed in the account of the tertiary strata and diluvia; but the formation of mineral coal will be much better understood by tracing the gradual conversion of vegetable matter into substances approaching to the character of true coal.

impressions; by its close similarity to wood coal, (which is undoubtedly a vegetable product;) and, lastly, by the decisive fact, that some mineral coal, in the Dudley coal-field, is entirely composed of layers of mineralized plants.

Though the vegetable origin of mineral coal may be satisfactorily established, there is considerable difficulty in conceiving by what process so many beds and seams of coal have been regularly arranged over each other in the same coal-field, and separated by strata of sandstone, shale, and indurated clay. It will tend to simplify the inquiry, if we examine a coal-field of very limited extent; such as those which occur in small coal basins, called *swilleys*, on the hills in the West Riding of Yorkshire, and which are not more than one mile in length and breadth. It seems evident, that these basins have once been small lakes or marshes, and that the strata have been deposited on the bottom and sides, taking the concave form, which depositions under such circumstances must assume: and it is deserving notice, that the stratum of coal, which in one of these coal basins at Hudswell is a yard thick in the lowest part, gradually diminishes as it approaches the edges, and then entirely vanishes. This fact proves, that the present basin-shaped position of the strata was, in this case at least, their original one; and that the basin, at the period when the coal strata were formed, was a detached lake or marsh, and not part of the bed of the sea.

It has been supposed that coal strata were deposited on the bed of the ocean; but this is not probable, for the vegetable remains, so abundant in the coal strata, belong to families of terrestrial or marsh plants, ferns, gigantic equisetums, (horsetail,) with jointed and striated stems like reeds, hence called calamites, and lycopodia allied to ferns: these compose the greater part of the fossil plants accompanying coal. In some instances, the coal is decidedly formed of such plants; and, from the plants being sometimes found erect, we may infer that they grew near the place where they occur. A further proof of the fresh-water formation of coal strata, is afforded by a stratum of indurated clay in the Yorkshire and Derbyshire coal-fields. It occurs about the middle of the series, and is filled with the shells of fresh-water muscles. This stratum is called *muscle bind*, and will be particularly referred to in the next chapter. It deserves notice, that the substance of shells in the coal shale, at least wherever I have seen them in the northern coal-fields, has that cretaceous or chalky appearance and consistence, which I have observed to be peculiar to shells in what are regarded as undoubted fresh-water formations.

If the basins in which the coal strata are deposited were originally fresh-water lakes or marshes, did any of the plants, whose remains compose coal, grow where the coal is now found? or,

were they carried by rivers or inundations into the lakes, and gradually deposited as the water evaporated ? The former is perhaps the most probable hypothesis; and the occurrence of the same peculiar kind of fire clay under each bed of coal, favors the opinion, that this was the soil proper for the production of those plants from which coal has been formed. If we suppose that these lakes were periodically laid dry, and again filled by sudden inundations, we shall have the conditions required for the succession of carbonaceous and earthy strata that take place in a coal-field : a repetition of such inundations would fill up the lake or basin. Nor can such a supposition appear improbable; for, as the species of vegetables in the coal strata are analogous to what at present grow in tropical climates, we may infer that they were subjected to such atmospheric influences as promote the rapid growth and decay of vegetation in hot countries, accompanied with great periodical inundations.

The terrestrial and marsh plants that accompany coal, and of which it was formed, might flourish between these successive inundations, their growth being sufficiently rapid to form a thick bed of vegetable matter in a short period; for, as they had not the ligneous structure of wood, their decomposition by vegetable fermentation might speedily be effected. Should it be objected, that some of the coal beds are from nine to thirty feet in thickness, and that a mass of vegetable matter, sufficient to form such beds, could not be collected in one season, it might be said in reply, that we know not the duration of the periods during which vegetation might proceed without interruption; but it deserves particular notice, in relation to this subject, that all thick beds of coal are divided into several minor strata, and have frequently thin strata of shale, clay, or sandstone between them, though they are called by the miners one bed, as the coal can be all got at the same level. The Staffordshire coal stratum, which is thirty feet thick, is divided into thirteen minor strata by seams of clay, &c.; and the thirteen feet bed of coal at Ashby Wolds, is composed of several seams of different qualities, which have different names given to them by the miners.

Very thin seams of coal sometimes alternate with the shale lying between two large beds of coal. I have on the table before me, a mass from the Dudley coal-field, in which part of two beds of coal are separated by a stratum of indurated clay or shale, about two inches in thickness; this stratum of shale contains more than twenty seams of coal, none of which exceed the thickness of a wafer, but they are distinctly separated from each other by seams of shale. These thin seams of coal and shale were probably formed by alternate depositions of leaves or minute aquatic plants, and of earthy particles forming layers of clay or sand. These are circumstances which appear to me to prove,

that the formation of the coal strata was effected more rapidly than those geologists have hitherto been willing to admit, who have only examined coal mines, seated in an easy chair in their studies. The frequent repetition of certain series of strata of precisely the same quality and thickness at different depths in the same mine, is well deserving notice, as it indicates a periodical recurrence of the same conditions under which they were deposited. A remarkable instance of such recurring series, in the mine belonging to the Marquis of Hastings, which I examined in 1812, will be stated at the end of the present chapter.

Vertical stems of plants occur in coal-fields: this may have been their original locality, but it is seldom that they can be seen in this position, unless in situations where a considerable face of rock, composed of coal measures, is open to the day.

In 1819, I had an opportunity of examining Burntwood quarry, at Althouse, near Wakefield in Yorkshire, at which time there were numerous vertical stems in strata of sandstone, the upper series of the coal measures. One stem which I measured in the quarry was nine feet in length, and ten inches in diameter; but, what is remarkable, this stem passed through three strata of sandstone, parted by regular strata seams. It had, therefore, evidently grown in the situation where it stood; for it is difficult to believe that any vegetable stem could pierce through three strata of sandstone, the lower of which, at least, must have been partly consolidated. When we consider that these were the stems of hollow tubular plants, equisetums, without any woody support, it is impossible to believe that they could have remained erect, in a warm temperature, without speedy destruction or decomposition, even for a very limited time. We are therefore certain, that they were speedily encased in the strata that now surround them, or, in other words, that three strata of sandstone, nine feet in thickness, were rapidly deposited.

The coal mines at St. Etienne, in France, present similar appearances; the vertical stems are numerous, and ten or twelve feet in length. From a drawing and description of them given me by M. Alexandre Brongniart, it appears that they were large equisetums, and the hollow tube is filled with sandstone. The circumstances and the inferences from them, agree with those before stated of Burntwood quarry.

In the section of the Ashby-de-la-Zouch coal, given at the end of this chapter, it will be seen, that there are no less than sixteen strata of blue bind, exactly of the same thickness, and alternating with sixteen strata of ironstone, of which the six upper are only one inch in thickness, and the lower two inches. If we should suppose each stratum of bind and ironstone to have been deposited in different parts of one year, we should have a speedy formation of these thin beds. We know nothing, however, cer-

tain, respecting the formation of ironstone; but it appears to have been deposited in fresh water, as it occurs in fresh-water strata in the regular coal formation, and in the coal strata of the oolites in Yorkshire, and among the clay and sandstone strata in the wealds of Kent. Few geologists have attempted to explain the formation of ironstone. It may have been a deposition from chalybeate waters, or was, perhaps, the produce of decomposed vegetation, as bog or peat iron is supposed to have been.

Some geologists are of opinion, that coal was formed from peat; but the fossil vegetables in coal strata, and in the coal itself, are not what compose the peat of the present day. However, if northern latitudes had the temperature of tropical climates during the geological epoch when the vegetables flourished that are found in the coal strata, the peat of that period would partake of a different character from recent peat beds, and might be produced by the rapid decomposition of the large terrestrial and marsh plants, before referred to. A bed of modern peat, seven feet in thickness, is said to have been formed in thirty years; but the primitive vegetation of the world, flourishing and decaying under a high degree of temperature, and a moist atmosphere, might form thick beds of peat in a much shorter period.

It is truly deserving attention, that the vegetable fossils found in distant parts of the world, and under very different latitudes, are nearly identical with those in European coal-fields. The plants in the coal-fields of North America, and even the specimens from Greenland, are analogous to those in the English coal-fields; and the few specimens that have been obtained from the tropical regions in America, from New Holland, and from India, belong to the same families as those which we find in the coal strata of Europe. Now, if we admit these distant beds of coal to be of contemporaneous formation, we must admit also, that the temperature of the whole globe was, at that epoch, nearly the same in very different latitudes; or were we to suppose that these coal-fields were formed in different epochs, we must still grant, that northern latitudes have once enjoyed the same temperature, as countries under the equator.

Before concluding these observations, it may be permitted to remark, that, however ancient the formation of coal and ironstone may have been, the frequent occurrence of these minerals together, both destined in future time to give to man an extensive empire over the elements, and to contribute largely to his means of civilization and comfort, cannot fail to impress the reflecting mind with evidence of prospective designing intelligence.

The conversion of vegetable matter into true mineral coal has been admirably elucidated by the experiments of Dr. MacCulloch on wood in different states of bituminization, from submerged wood, to peat, brown coal, surturbrand, and lastly to

jet, in which the traces of organization are nearly destroyed. These substances, which have been only subjected to the action of water, all yield bitumen by gentle distillation; but they differ from mineral coal, by yielding also a large portion of acetic acid, which marks the remains of undecayed vegetable substances. Common coal has formerly been regarded as a combination of charcoal with bitumen; but as bitumen is itself a combination of carbon with hydrogen, Dr. MacCulloch says, it will be more proper to consider coal as a bitumen, varying in its composition from the fattest Newcastle coal to the driest Kilkenny coal, and owing its compactness to the peculiar circumstances under which it has been formed, the changes it may have subsequently undergone, and the substances intermixed with it. The power of yielding naphtha by distillation, is the distinction between one end of the series and the other. The last link (anthracite) contains only carbon; so the last result of the distillation of asphaltum is also carbon.

To convert wood coal or jet into true coal, some further process than long submersion in water seems necessary. The latter substance, jet, was reduced to powder by Dr. M., and put into a gun-barrel, and covered close with Stourbridge clay; it was then exposed to a moderate red heat. By this process, it was converted into a substance having all the external characters and chemical properties of true mineral coal, and the clay was converted into coal shale. But though, in the laboratory of the chemist, the last stage of the formation of coal requires artificial fire, yet in the great laboratory of Nature, vegetable fermentation and compression may evolve sufficient heat for the ultimate formation of mineral coal. It may, however, deserve notice, that most great repositories of coal are intersected by beds and dykes of basalt, which is now admitted to be of igneous origin.*

Pressure and time alone may be sufficient to produce the destruction of vegetable organization, and the perfect consolidation of beds of coal, as is proved by the complete consolidation of loose materials left in coal mines when the supports are removed, and the upper strata sink down. In a few years, scarcely a trace of former operations remains. In contemplating natural causes, we are too apt to measure their power by the results of artificial processes, and by observations continued for a short portion of human life. The substances found in the neglected vessels of the chemist, often prove to us, that changes in the physical properties of bodies are effected by time, which it would be difficult to imitate in common experiments.

---

* At Meisner, in Hesse, a thick bed of wood coal or lignite is covered by an enormous mass of basalt, and is only separated from it by a thin bed of clay. The upper parts of the lignite are converted into anthracite, and even into true bituminous coal, while the lower parts are formed of earthy and fibrous wood coal.

The great regular coal formations in England and Wales, generally occur resting on transition limestone. In some situations, the under transition rocks are wanting, and the series of coal strata rest on granite, with the intervention of a thick bed of conglomerate.

No mineral coal, both good in quality and abundant in quantity, has ever been found, either in the primary or in the lower transition rocks, or in the upper secondary or the tertiary strata. It is true, that in the oolite of the upper secondary strata, two series of coal strata occur on the eastern moorlands of Yorkshire, which are thought of sufficient importance to be worked; but the coal is very indifferent, and is chiefly used by the lime burners. This coal formation will be noticed in a subsequent chapter. The Kimmeridge clay in the oolites also contains beds of shale impregnated with bitumen, which is used as fuel in a country where coal is extremely dear.

The wood coal of Bovey Heathfield has been already noticed. I may state in addition, that I visited the mine in 1815: it is worked like an open quarry; it had been for some years previously under water, but was then laid dry by pumps. There are several irregular beds of lignite or wood coal, alternating with what is called dead coal, which is less inflammable, and resembles a bituminous shale; the beds wedge out narrow as they descend. The whole mass is more or less bituminized; but the upper part, which preserves the woody structure more perfectly, seems principally composed of clay. Sulphate and carbonate of iron occur in some part of the beds, and rounded pieces of maltha. Wood coal occurs chiefly in diluvial deposits. Where wood coal is covered with basalt, it is converted into a substance nearly resembling mineral coal. This coal occurs in Iceland, in the north of Ireland, and in many basaltic districts on the Continent.

Before concluding this brief account of imperfect coal formations, out of the limits of the regular coal formation, I would direct the attention of geologists to two situations in which coal is found, that are well deserving of notice. The first is the mine of Entreveines, situated in a mountain valley about two thousand feet above the lake of Annecy, and at least three thousand five hundred feet above the level of the sea. The bed of coal consists of three minor beds, separated by thin seams of clay varying in thickness, yielding about four feet of good coal, which has the character and fracture of mineral coal; it is shining, does not soil the fingers, and is highly bituminous, being exclusively used for the gas lights in the cotton mills at Annecy. The total thickness of the sandstone, shale, and coal strata, which compose the coal formation in this place, is about one hundred and fifty yards; they are placed between thick beds of limestone, and dip together

at an angle of about seventy degrees.* It is worthy of observation, that the limestone beds above and below the coal formation, have the hardness, fracture, translucency, and appearance of the transition limestone at Plymouth; yet in another part of the mountain, the same limestone is associated with a bed of dark clay, in which I found gryphites and belemnites, clearly indicating that the bed was analogous to our lias or clunch clay; and that the limestone associated with it, norwithstanding its mineral character, belonged to the upper secondary strata; and hence that the coal, in geological position, agreed with the imperfect coal formations in the English oolites. Here, then, we have a further proof of what has before been stated, that in the calcareous formations of the Alps, the upper secondary strata lose the soft and earthy character which distinguish the oolites and chalk in England, and are converted into marble. The coal also, which is very imperfectly formed in the English oolite, has, in the same limestone formation in the Alps, the character of true mineral coal.

A still more remarkable coal formation occurs at Alpnach, near the lake of Lucerne in Switzerland, where a bed of coal is found at the depth of two hundred and eighty feet from the surface. Over the coal, there is a stratum of bituminous limestone containing fluviatile shells, and bones and teeth of the large mammalia, particularly the teeth of a species of mastodon. The specimens which were shown me by Professor Meissner of Berne, on my return from the Swiss Alps, made me regret exceedingly not having visited Alpnach. Notwithstanding the occurrence of the bones of large land quadrupeds in the stratum over the coal, the coal approaches in character nearly to mineral coal, and the strata of micaceous sandstone and shale above it, have a close resemblance to those in our English coal-fields. Though, from the organic remains, we are compelled to place the coal of Alpnach among the tertiary strata, or to admit the occurrence of an anomalous formation like the one at Stonesfield, still I believe the true geological position of the coal of Alpnach is problematical; and it deserves the particular attention of some English geologist, well acquainted with the different coal-fields in his own country, and the lignite formations in various parts of Europe.

It will be seen by a reference to the geological map, and the chapter containing an outline of the geology of England, that there is a considerable part of South Britain where coal has not been found. Two important questions may be asked;—Do the coal strata extend under the parts where coal has not yet been discovered? And if they do extend beyond their present known

* A particular description of this singular coal mine, with a cut illustrating the position of the beds, is given in Vol. I, of my "Travels in the Tarentaise," &c.

limits,—what practicable means can be employed to obtain the coal? With respect to the first question, it is well ascertained by boring, that the coal strata do in some places extend under the magnesian limestone, by which they are immediately covered in some of the northern counties, though it was formerly supposed that the coal terminated before it reached the magnesian limestone, or was there cut off by a fault. In a considerable part of England, the coal-fields are immediately covered by what is called the red marl, or new red sandstone; but there are few situations where the red marl and sandstone have been sunk through for coal. "I am, however, decidedly of opinion, that under the red marl adjacent to the coal districts in my native county, Nottinghamshire, the regular coal strata will be found; and that there is a high degree of probability that rock salt or brine springs will be found in the red marl itself, particularly in those parts of the county where beds of massive gypsum occur.* The same remark might be extended to the red marl and sandstone districts adjoining coal strata in Derbyshire, Leicestershire, and Warwickshire."† In confirmation of the opinion here advanced, a saline spring has in consequence been discovered about four miles north-west of Nottingham; and coal has been lately found under the red marl and sandstone on the south side of Charnwood Forest, where it had not before been suspected to exist. It may, however, be proper to say, that no search of this kind by boring should be undertaken by any one, to whom the expense, in case of failure, would be a serious inconvenience.

The dip and direction of the strata in the coal-fields nearest to the estate where the search is to be made, should be well known. If the strata dip towards the estate, it is probable the coal may extend under it: if they dip from it, the search should not be undertaken. To make this intelligible, see Plate III, fig. 3; *a, a, a*, are a series of coal strata, or, as they are provincially called, coal measures, dipping toward the side B. *c, c, c*, are strata of red marl or sandstone, lying unconformably over the coal strata. Now, according to this arrangement, a search for coal might be successful, though the bed might be at too great a depth to be worked. Whereas on an estate at D, as the coal strata dip from it, were we to bore to the centre of the earth, we could never find the beds 1, 2, 3, 4. If the estate B is situated a considerable distance from a known coal-field, the strata of coal may bend as represented Plate IV, fig. 2, and crop out at *a*, before they reach the station *b*, where the trial is made; and if the outcrop be covered by the red sandstone, this cannot be known but by trial.

---

* Third edition, 1828.

† Since the third edition of this work was published, coal has been found under the red marl and sandstone near Manchester.

Rock salt or brine springs are most likely to be found by boring in the vicinity of massive gypsum, without regarding the stratification. As for the districts where the upper secondary strata of lias, oolite, and chalk occur, all search for the regular coal strata must there be fruitless; as the vast thickness of these calcareous formations precludes the hope of success.

Coal mines, it is well known, are subject to fatal explosions of what is called the fire-damp, or carburetted hydrogen gas. This gas appears to be generated by the decomposition of iron pyrites in coal, and may often be heard issuing from the fissures in coal beds with a bubbling noise, as it forces the water out along with it. The choke-damp, as it is called, is either carbonic acid gas, (fixed air,) or the unrespirable residue of air left after explosions, when all the oxygen is consumed. (See Appendix.)

The regular or great coal formation has never been discovered at a very considerable elevation above the level of the sea: it generally is found towards the feet of great mountain chains, or in the valleys near to lofty mountain ranges. The geology of large portions of the globe is still unknown; but it appears from those parts with which we are acquainted, that coal is principally found in temperate regions, between thirty five and sixty five degrees of latitude. In Europe,—Great Britain, France, Flanders, and Germany, (particularly Silesia, Saxony, Bohemia, and Thuringia,) contain large coal formations; but in the southern and more northern parts of Europe, coal is of rare occurrence. In North America, coal is found in great abundance on the western side of the Alleghany mountains; it has also been discovered in Pennsylvania, extending westward towards Pittsburgh, over a space of three hundred miles. Coal occurs also near Richmond, in Virginia, and in Missouri. American coal is said to be found in quartz rock, which I apprehend to be merely siliceous grit, composed of nearly pure granular silex, such as abounds in the lower part of the Yorkshire coal-fields. The coal, in a great part of the United States, contains little bitumen, and hence is called anthracite, but it is not the true anthracite of mineralogists, but far more valuable for fuel. The discovery of this immense repository of coal, accompanied with ironstone, must prove of the highest importance to a nation so industrious, intelligent, and enterprising, as the inhabitants of the United States.* In the vicinity of Pittsburgh, I am informed, that the strata of coal are nearly horizontal, and that in one situation, the same stratum of coal forms the bed of a river for several miles. Coal has been discovered in New Holland. The only great coal formations in Asia that we know of are in China, where coal is described as existing

* A farther account of the American coal-fields will be given in the Appendix.

in large quantities, and as being extensively used for fuel in that vast empire.

As France will probably continue to be for many centuries our great manufacturing rival, it is interesting to know what are her resources, for the supply of an article found so essential to almost all the principal manufactures of Great Britain. Before the late peace, forty seven of the departments contained coal districts, and the annual consumption was stated to be about five million tons; but a great part of the rich and extensive coal-field extending from Valenciennes to Aix la Chapelle, is comprised in that part of Flanders, which was separated from France at the peace. There are, however, extensive coal districts in the northeastern, the western, the middle, and the southern parts of France. Two miles from Lyons there are coal mines. The coal of St. Etienne and the ironstone beds accompanying it, about twenty miles northwest of Lyons, are of the very best quality. In the year 1822, when I passed through that country, many English workmen were employed in the iron works, which were rapidly increasing. It cannot be doubted that France possesses every advantage, from its soil, its climate, and its mineral resources, which a great manufacturing nation can require.

OBSERVATIONS ON THE PERIOD WHEN THE COAL MINES IN ENGLAND WILL BE EXHAUSTED.

Coal was known, and partially used, at a very early period of our history. I was informed by the late Marquis of Hastings, that stone hammers and stone tools were found in some of the old workings in his mines at Ashby Wolds; and his lordship informed me also, that similar stone tools had been discovered in the old workings in the coal mines in the north of Ireland. Hence we may infer, that these coal mines were worked at a very remote period, when the use of metallic tools was not general. The burning of coal was prohibited in London in the year 1308, by the royal proclamation of Edward the First. In the reign of Queen Elizabeth, the burning of coal was again prohibited in London during the sitting of parliament, lest the health of the knights of the shire should suffer injury during their abode in the metropolis. In the year 1643, the use of coal had become so general, and the price being then very high, many of the poor are said to have perished for want of fuel. At the present day, when the consumption of coal, in our iron furnaces and manufactories, and for domestic use, is immense, we cannot but regard the exhaustion of our coal beds as involving the destruction of a great portion of our private comfort and national prosperity. Nor is the period very remote, when the coal districts, which at present supply the metropolis with fuel, will cease to yield any more. The annual quantity of coal shipped in the rivers Tyne and Wear, according to Mr. Bailey, exceeded three million tons. A cubic yard of coal weighs nearly one ton; and the number of tons contained in a bed of coal one square mile in extent, and one yard in thickness, is about four millions. The number and

extent of all the principal coal beds in Northumberland and Durham are known; and from these data it has been calculated, that the coal in these counties will last 360 years. Mr. Bailey, in his Survey of Durham, states, that one third of the coal being already got, the coal districts will be exhausted in 200 years. It is probable that many beds of inferior coal, which are now neglected, may in future be worked; but the consumption of coal being greatly increased since Mr. Bailey published his Survey of Durham, we may admit his calculation to be an approximation to the truth, and that the coal of Northumberland and Durham will be exhausted in a period not greatly exceeding 200 years. Dr. Thomson, in the Annals of Philosophy, has calculated that the coal of these districts, at the present rate of consumption, will last 1000 years; but his calculations are founded on data manifestly erroneous, and at variance with his own statements: for he assumes the annual consumption of coal to be only two million eight hundred thousand tons, and the waste to be one third more,—making three million seven hundred thousand tons, equal to as many square yards; whereas he has just before informed us, that two million chaldrons of coal, of two tons and a quarter each chaldron, are exported, making four million five hundred thousand tons, beside inland consumption, and waste in the working.* According to Mr. Winch, three million five hundred thousand tons of coal are consumed annually from these districts; to which, if we add the waste of small coal at the pit's mouth, and the waste in the mines, it will make the total yearly destruction of coal nearly double the quantity assigned by Dr. Thomson. Dr. Thomson has also greatly overrated the quantity of the coal in these districts, as he has calculated the extent of the principal beds from that of the lowest, which is erroneous: for many of the principal beds crop out, before they reach the western termination of the coal-fields. With due allowance for these errors, and for the quantity of coal already worked out, (which, according to Mr. Bailey, is about one third,) the 1000 years of Dr. Thomson will not greatly exceed the period assigned by Mr. Bailey for the complete exhaustion of coal in these counties, and may be stated at 350 years.

It cannot be deemed uninteresting to inquire, what are the repositories of coal that can supply the metropolis and the southern counties, when no more can be obtained from the Tyne and the Wear. The only coal-fields of any extent on the eastern side of England between London and Durham, are those of Derbyshire, and those in the West Riding of Yorkshire. The Derbyshire coal-field is not of sufficient magnitude to supply, for any long period, more than is required for home consumption, and that of the adjacent counties. There are many valuable beds of coal in the western part of the West Riding of Yorkshire, which are yet unwrought; but the time is not very distant, when they must be put in requisition, to supply the vast demand of that populous manufacturing county, which at present consumes nearly all the produce of its own coal mines. In the midland counties, Staffordshire possesses the nearest coal district to the metropolis, of any great extent; but such is the immense daily consumption of coal

* The waste of the coal at the pit's mouth may be stated at one sixth of the quantity sold, and that in the mines at one third. Mr. Holmes, in his Treatise on Coal Mines, states the waste of small coal at the pit's mouth to be one fourth of the whole.

in the iron furnaces and founderies, that it is generally believed, this will be the first of our own coal-fields that will be exhausted. The thirty feet bed of coal in Dudley coal-field is of limited extent; and in the present mode of working it, more than two thirds of the coal is wasted and left in the mine.

If we look to Whitehaven or Lancashire, or to any of the minor coal-fields in the west of England, we can derive little hope of their being able to supply London and the southern counties with coal, after the import of coal fails from Northumberland and Durham. We may thus anticipate a period not very remote, when all the English mines of coal and ironstone will be exhausted: and were we disposed to indulge in gloomy forebodings, like the ingenious authoress of the "Last Man," we might draw a melancholy picture of our starving and declining population, and describe some manufacturing patriarch, like the late venerable Richard Reynolds, travelling to see the last expiring English furnace, before he emigrated to distant regions.*

Fortunately, however, we have in South Wales, adjoining the Bristol Channel, an almost exhaustless supply of coal and ironstone, which are yet nearly unwrought. It has been stated in the present chapter, that this coal-field extends over about twelve hundred square miles, and that there are twenty three beds of workable coal, the total average thickness of which is ninety five feet, and the quantity contained in each acre is 100,000 tons, or 65,000,000 tons per square mile. If from this we deduct one half for waste, and for the minor extent of the upper beds, we shall have a clear supply of coal equal to 32,000,000 tons per square mile. Now, if we admit that the 5,000,000 tons of coal from the Northumberland and Durham mines is equal to nearly one third of the total consumption of coal in England, each square mile of the Welch coal-field, would yield coal for two years' consumption; and as there are from one thousand to twelve hundred square miles in this coal-field, it would supply England with fuel for two thousand years, after all our English coal mines are worked out.

It is true, that a considerable part of the coal in South Wales is of an inferior quality, and is not at present burned for domestic use; but in proportion as coal becomes scarce, improved methods of burning it will assuredly be discovered, to prevent any sulphurous fumes from entering apartments, and also to economize the consumption of fuel in all our manufacturing processes.

N. B. These observations are chiefly taken from one of the author's geological lectures, which he has occasionally delivered in some of the principal mining districts in England: considering the great national importance of our coal mines, he trusts he shall be excused for inserting them in the present volume.

---

* The late Richard Reynolds, Esq. of Bristol, so distinguished for his unbounded benevolence, was the original proprietor of the great iron works in Colebrook Dale, Shropshire. Owing, I believe, partly to the exhaustion of the best workable beds of coal and ironstone, and partly to the superior advantage possessed by the iron founders in South Wales, the works of Colebrook Dale were finally relinquished, a short time before the death of Mr. Reynolds. With a natural attachment to the scenes where he had passed his early years, and to the pursuits by which he had honorably acquired his great wealth, he travelled from Bristol into Shropshire, to be present when the last of his furnaces was extinguished, in a valley where they had been continually burning for more than half a century.

ADDITIONAL REMARKS ON THE DURATION OF ENGLISH COAL.

Since the above observations were first published, the consumption of coal has increased to an almost incredible extent, particularly in the iron works. From $5\frac{1}{2}$ to 6 tons of coal are required on the average for the production of one ton of iron. In the year 1827, the amount of iron produced in Great Britain and Scotland was nearly 700,000 tons; this is about three times the quantity made in 1806, or twenty one years previously. The quantity of iron made in 1836, is stated in the Mining Journal, October 7, 1837, to be about 1,000,000 tons. In the manufacture of this iron into pigs and bars, 6,000,000 tons of coal would be consumed, which is a greater quantity than the coal mines of Northumberland and Durham are said to supply annually.

In the report of the committee of the House of Commons, the consumption of coal in Great Britain in the year 1827, is stated as under:

	Tons.
Domestic consumption and smaller manufactures	15,000,000
Production of pig and bar iron	3,850,000
Cotton manufacture	800,000
Woollen, linen, and silk	500,000
Copper smelting and brass manufacture	450,000
Salt works	300,000
Lime works	500,000
Exports to Ireland	750,000
Ditto to Colonies, foreign parts	600,000
	22,700,000

In this estimate no allowance is made for the coal consumed in the manufacture of hardware and cutlery in Birmingham and Sheffield: the amount may therefore be taken as considerably under the quantity consumed. The increasing demand for coal in the iron furnaces, and for steam navigation, and steam carriages, will probably soon raise the quantity of coal annually consumed to 30,000,000 tons without adding to this 10,000,000 of tons for coal left and wasted in the mines. A better idea of the consumption of coal will perhaps be formed by stating the quantity of coal burned in the furnaces of one house only, (Messrs. Guest, of Myrthyr Tydvil, in Glamorganshire,) which is 970 tons per day, or 300,000 yearly; the amount of iron produced is 50,000 tons. This is a larger quantity of iron than was made by all the furnaces of Great Britain and Wales in the year 1760, and exceeds the quantity of iron at present made in Scotland, which in 1827 was only 36,500 tons.

Surely when such an immense quantity of coal is required for domestic use and manufactures, it cannot be wise to encourage, or even to admit, the export of coal to foreign parts. The coal so exported, exclusive of that to Ireland and the Colonies, is about 500,000 tons annually. The duty on exported coal was entirely taken off in 1835, to satisfy the great landed proprietors in the north of England. I have stated in the preceding observations, that the coal of Northumberland and Durham would, at the present rate of consumption, be exhausted in 350 years. An agent of one of the northern proprietors, in his evidence before the House of

Commons, extended the duration of the northern coal-fields to 1727 years, estimating that there remained 732 square miles of coal in Northumberland and Durham still unwrought, and that the average thickness of the coal is twelve feet. In this calculation it appears to have been assumed, that each workable bed of coal extends under the whole coal-field, but many of the best and thickest beds of coal, crop out long before they reach the western termination of the coal districts, or are cut off by faults or denudations. Professor Buckland, in his evidence on this subject, estimated the duration of the coal, at the present rate of consumption, to be 400 years. Professor Sedgwick, who is well acquainted with the coal strata of Northumberland and Durham, and had examined persons of great experience, gave his opinion respecting the duration of the coal of these counties as follows :—" I am myself convinced, that, with the present increased and increasing demand for coal, 400 years will leave little more than the name of our best coal seams ;" and he further adds, " our northern coal-field will probably be in the wane before 300 years have elapsed."

At the conclusion of my observations on the exhaustion on the English coal mines, in the former editions, I suggested, "that improved methods of burning coal would assuredly be discovered to economize the consumption of fuel in our manufacturing processes." This anticipation seems now to be realized to a great extent. It was stated at the last meeting of the British Association at Liverpool, by Mr. Crane of the Ynscedwin iron works, in South Wales, that he had discovered that the culm, or dry coal, of the great South Wales coal basin, which is supposed to occupy one third of that basin, might now be applied, with great advantage, to the smelting of ironstone or ore, without coking. It had formerly been often attempted to use this coal in the iron furnaces but without success, because it would not coke, and was also difficult to ignite. Mr. Crane has fortunately discovered, that by employing what is called the hot blast, or a current of air at a high temperature, the culm burned freely in the furnace, and answered better than the coke from bituminous coal. It also produced iron of a superior quality; but what is more remarkable and important, Mr. Crane had, during three months, obtained, on the average, one ton of iron from the consumption of only twenty seven cwt. of culm, whereas it required from five to six tons of bituminous coal to produce the same quantity of iron.

Dr. Thomson, in a valuable paper, read at the same meeting, on the effects of the hot and cold blast, as applied to the iron furnaces of Scotland, stated that, by introducing the hot blast, bituminous coal might be used without coking, and that a ton of iron could be produced by two tons nineteen cwt. of coal, which will be a saving of more than three tons for every ton of iron obtained. If the use of the hot blast is found every where to succeed, the consumption of coal in the iron furnaces will be reduced one half. It may, however, be doubted, whether this reduction will equal the increasing demand for coal for steam vessels and rail-road carriages, and the various manufactures of Great Britain.

SECTION OF A COAL MINE ON ASHBY WOLDS.

The following section was given me by Mr. Woodhouse, the engineer to the mines of the Marquis of Hastings, who had carefully inspected and measured each stratum, when the shaft was sunk. This mine was the deepest that had then (1812) been worked on the estate: since that date a deeper mine has been sunk to the same bed in another part of the field. An account of this coal-field has been recently published by the late Mr. Mammott, who became principal agent for the Marquis at the time I was examining the property. Mr. M. has carefully and correctly described the particulars of this coal-field, but it does not appear that any new facts relating to it have been discovered since I was there, except that two lower beds of workable coal have been found under the main coal.

The subject to which I wish to direct the attention of the reader in the following section, is the frequent recurrence of similar beds of equal thickness at different depths. If ever we arrive at just conclusions respecting the origin of coal and ironstone, it must be by an accurate examination of the strata in which they occur, and the relation of these strata to each other; an investigation hitherto much neglected by geologists.

TABULAR SECTION OF THE MOIRA COAL MINE, ASHBY WOLDS, LEICESTERSHIRE.

		Yds.	Ft.	In.
	Soil and Clay	2	0	0
1	Blue clunch with ironstone	1	2	5
	COAL	0	1	6
	Blue bind	1	0	0
	Stony bind	0	1	2
	Grey stone	0	0	4
	Stony bind	1	0	9
	Grey stone	0	1	9
	Blue bind	3	2	1½
	Grey stone	0	1	1
	Rubly bind	0	2	0
	Blue bind	4	0	0
	Black bat	0	2	0
2	Black bind with ironstone	1	1	0
	COAL	0	1	5
	Blue bind	3	1	0
	Black bat and black bind	0	2	3
	Stony bind	2	2	6
	Blue bind in two beds	6	1	0
	Black bat	0	2	0
	Blue bind	3	0	0
3	Ironstone	0	0	1
	Blue bind	0	1	6
4	Ironstone	0	0	1
	Blue bind	0	1	6
5	Ironstone	0	0	1
	Blue bind	0	1	6
6	Ironstone	0	0	1
	Blue bind	0	1	6
7	Ironstone	0	0	1
	Blue bind	0	1	6
8	Ironstone	0	0	1
	Blue bind	2	9	0
	COAL	1	0	0
	Blue bind in two beds	9	0	0
	Stony bind	1	1	0
	Grey stone	3	0	0
9	Blue bind	0	1	6
	Ironstone	0	0	2
10	Blue bind	0	1	6
	Ironstone	0	0	2
11	Blue bind	0	1	6
	Ironstone	0	0	2
12	Blue bind	0	1	6
	Ironstone	0	0	2

		Yds.	Ft.	In.
13	Blue bind -	0	1	6
13	Ironstone -	0	0	2
14	Blue bind -	0	1	6
14	Ironstone -	0	0	2
	Blue bind -	1	2	9
15	Ironstone -	0	0	$2\frac{1}{2}$
	Black bind -	1	1	6
	Blue bind -	0	1	6
	Coal - -	1	0	0
	Blue and black bind - -	4	2	0
	Dark stone -	5	2	2
	Black bat -	0	2	6
	Grey stone -	1	1	5
	Stony bind -	1	0	0
	Grey stone -	1	2	4
	Black bat -	3	0	2
16	Blue bind with balls of ironstone - -	3	2	1
	Black bat -	1	0	0
	Coal - -	1	0	4
	Grey stone -	10	0	0
17	Blue bind -	0	4	10
17	Ironstone -	0	0	2
	Blue and black bind alternating - -	6	0	9
	Coal - -	0	1	9
	Rubly bind with ironstone balls	2	1	2
	Blue bind -	3	0	0
	Rubly bind -	2	0	0
	Black bind -	1	1	6
	Blue bind -	1	2	4
	Ironstone -	0	0	2
	Black bind -	0	2	0
	Blue bind -	1	2	0
	Black bind -	0	2	0
	Coal - -	0	2	0
	Stony bind -	3	0	3
	Blue bind -	3	0	8
	Black bind with coal - -	1	1	6
	Stony bind -	3	0	10

		Yds.	Ft.	In.
	Coal - -	1	0	8
	Stony bind -	0	1	6
	White stone -	3	0	0
	Stony bind -	5	0	9
18	Blue bind -	2	2	10
18	Ironstone -	0	0	2
19	Blue bind -	2	2	0
19	Ironstone -	0	0	2
	Blue bind -	1	2	6
	Grey stone -	0	1	6
	Rubly stone -	3	0	0
	Grey stone -	2	0	0
20	Blue bind and ironstone -	1	1	0
	Coal - -	1	1	0
	Stony bind with a little ironstone	4	0	0
	Blue bind -	0	1	6
	Rubly stone -	1	0	0
	Stony bind and grey stone -	6	1	6
	Stony bind -	1	2	2
	Kennel Coal	0	2	10
21	Ironstone -	0	0	$1\frac{1}{2}$
21	Blue bind -	1	0	0
22	Ironstone -	0	0	2
22	Blue bind -	0	1	6
23	Ironstone -	0	0	3
23	Blue bind -	0	1	6
24	Ironstone -	0	0	2
24	Blue bind -	1	2	1
25	Black ironstone	0	0	6
25	Black bind -	0	1	6
26	Ironstone -	0	0	2
27	Blue bind with a little ironstone	6	2	3
	Black bind with ditto - -	6	2	8
	Blue bind, ironstone balls -	6	1	0
	Rider, a roof of coal - -	1	1	0
	Upper main coal	1	0	9
	Main coal -	3	1	0

The aggregate thickness of the strata above the main coal in this mine is about two hundred and twenty yards, though from the basin-shaped form of the beds, the same coal rises to the surface at about three miles distant from the pit. At the Hastings mine, recently opened, the main coal is three hundred and thirty yards from the surface; and on boring

ninety six feet below this, two other beds of coal, each about three feet thick, have been found. The depth of the lowest bed is three hundred and seventy two yards, though in the centre of England, it is two hundred and eighty yards below the level of the sea, as ascertained by the levels of the Oxford canal, which passes over part of this coal-field. In the mine of which the above tabular section is given, there are about one hundred and thirty distinct strata, comprising ten beds of coal, and twenty seams of ironstone and strata containing ironstone. The main coal is from thirteen to fourteen feet in thickness, containing twenty seams of coal of different qualities. The lower seven seams are about six feet in thickness; they are not worked at present, but one of the seams is sufficiently hard to form a roof whenever the coal above it is worked out. The props or supports of the present roof will then be taken away, and the whole upper strata will gradually sink down. There is scarcely any water in this mine, and what is found there is saline, containing common salt nearly pure: it issues from the fissures in the coal with a hissing noise, being accompanied with carburetted hydrogen (fire damp.) All the beds of coal rest upon what is called bind, which is an argillaceous shale, more or less indurated, sometimes colored black by bitumen, and sometimes intermixed with sand resembling sandstone, but generally decomposing into a clayey soil (like the blue and black binds) on exposure to the atmosphere.

The recurrence of frequent alternations of seams of ironstone with thin beds of blue bind, each alternation preserving the same thickness, is a circumstance well deserving attention, as it indicates a periodical succession of causes probably dependent on the seasons.

There are a few beds in this coal-field called *rubly* or *rumilly* by the miners; they consist of loose materials and fragments, which indicate that they were transported during a violent and agitated condition of the water. Most of the other beds have evidently been slowly deposited in a very tranquil state of a lake or estuary.

CHAPTER IX.

ON THE GENERAL REMOVAL AND DISAPPEARANCE OF THE COAL STRATA RAISED BY FAULTS ABOVE THE SURFACE OF THE GROUND.—PROBABLE CAUSES OF THIS REMARKABLE PHENOMENON.—ON FAULTS AND FISSURES BEYOND THE LIMITS OF THE COAL DISTRICTS.

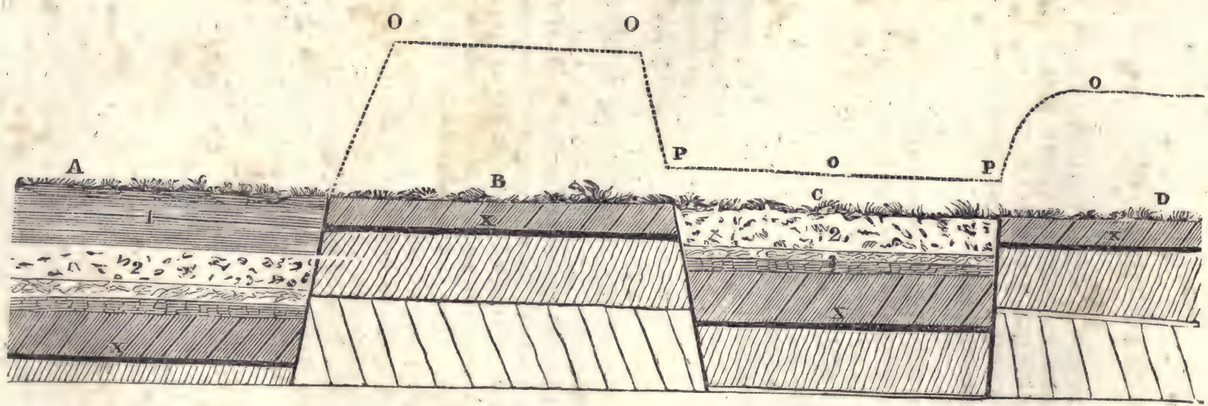
The strata, or measures, as they are called by coal miners, that compose the great coal formation, present to our notice some facts which have not hitherto received from geologists due attention: they relate to inquiries of the highest interest in the ancient history of the crust of our planet.

In the last chapter, a brief account was given of the faults or breaks that occur in coal strata, and often throw up or cast down the beds of coal on one side of the fault, many hundred feet or yards above or below the level at which they are found on the other side. This displacement of the coal strata by faults is represented in Plate IV, fig. 2 F, and fig. 3 d.

The most remarkable circumstance relating to faults in coal strata remains to be described.

However great may be the uprise or the downcast of the strata on one side of a fault, no indication of any disturbance is visible on the surface. A mass of upraised strata of many hundred feet in thickness, has by some unknown cause been carried away, and has entirely disappeared. The fact is general, and though it may truly be regarded as the most surprising geological phenomenon, yet like many other phenomena in nature of constant occurrence, it has scarcely excited attention. I propose in the present chapter to show, that a fact so general cannot be explained except by a general cause, acting under the same circumstances or conditions in the different coal-fields at the period or periods when the strata were disturbed.

No doubt similar disturbances have taken place in the strata below as well as above the great coal formation; but we have little accurate knowledge of them beyond the limits of mining operations. I shall therefore at first confine my inquiries to our known coal-fields, and shall afterwards offer some observations on the faults and fissures that extend beyond the coal formation, as some of the latter have evidently modified the present surface of islands and continents; but the disturbance produced by faults in the coal strata, is no where visible on the surface. If this be, as I have before stated, the most surprising fact that geology presents; an exposition of it, and of its probable cause, cannot be



A B C D. The surface of a coal-field, in which the strata are dislocated and elevated by faults.
The dotted line O O P O P O, marks the space that the upraised strata would have filled, had they not been removed by some unknown cause.
X X X X. The same bed of coal at different depths.

misplaced in an elementary work, particularly as I hold it to be some reproach to geologists, that the subject has been hitherto neglected or slurred over.*

The preceding cut will suffice to explain what is meant by the disappearance of the upraised strata. It represents the section of a coal-field several miles in extent, divided into four compartments, A, B, C, D, by faults, which have raised the strata to different depths from the surface. In the part of the field A, the main bed of coal X is nine hundred feet from the surface, and is covered by various strata of sandstone and shale, No. 1, 2, 3, &c. In compartment B, the same bed of main coal X, is raised to within two hundred feet of the surface, and the strata above are entirely wanting. In the compartment C, the main coal X, is seven hundred feet from the surface, and the strata No. 2 is found again over the coal. In compartment D, the main coal is brought within two hundred and fifty feet of the surface, and only a part of the strata No. 3 occurs. In the compartment B, the strata have been elevated seven hundred feet, and we might expect to see a corresponding elevation of the ground on that side of the fault, as represented by the dotted line at O O, and that the whole series of strata would form a hill seven hundred feet in height, whereas the surface of the ground over compartment A and B, presents no indication of any dislocation or upheaving of the beds. Over compartment C, representing a depression of coal strata five hundred feet below the level of the same strata in compartment B, we might expect to meet with a valley or depression of that depth on the surface, as at P P, but the surface on both sides of the fault is on the same level. Again, in that part of the coal-field at D, the strata have been raised six hundred and fifty feet, and the main coal is brought within two hundred and fifty feet of the surface; but here also no change of level takes place in the present outline of the country.

In all coal-fields that we have any knowledge of, where the strata are raised or depressed by faults, whether the elevation or depression be some hundred feet or yards, the surface of the

* Whatever blame may attach to geologists for neglecting or passing over a fact of so much importance as the disappearance of the upraised strata in coal districts, I am ready to acknowledge, that a full portion of this blame attaches to myself. When I first became acquainted with the fact, nearly thirty years since, I could not believe that it was of general occurrence, and I afterwards satisfied myself, like others, in calling the removal a case of denudation. In the fourth edition of this work, in 1833, I stated, that "the upraised strata were *sometimes* removed." On reading Mr. Mammott's account of the Ashby-de-la-Zouch coal-field, since published, and recollecting my impressions when I examined the same coal-field with him, twenty five years since, I was surprised to observe how inadequate was the cause assigned by him for the removal of the strata, either in this coal-field or any other in Great Britain; and this led me to investigate the subject with more attention. Mr. Mammott supposes that water has flowed violently over the surface of the land, and carried away the upraised strata.

ground, like that in the preceding section, bears no correspondence with the elevation or depression of the beds underneath.

Every rent or fissure that causes a dislocation of the strata, may be called a fault: but fissures filled with metallic ores and crystallized mineral matter, are generally denominated veins. The faults that intersect coal-fields are sometimes filled with basalt, and are called basaltic dykes; more frequently faults are filled with clay, sandstone, sand, and fragments of stone. In some instances, the sides of faults are in close contact, and present smooth polished surfaces, evidently occasioned by the friction of the ends of the strata, grinding against each other, at the time when they were fractured and displaced. This fact indicates, that the upheavings of the strata near such a fault was effected by a sudden movement, like what takes place during violent earthquakes, but such earthquakes on land often leave permanent cliffs and terraces, as proofs of the violence of their action.

Faults in the strata, if of great extent or depth, appear to have been made by an expansive force from beneath, opening a passage for aqueous vapor, or some elastic gas, or for melted mineral matter, which has immediately flowed into the fissure, and sometimes poured over the surface, like beds of lava formed at present in volcanic districts. The faults, filled by the ejection of melted mineral matter, form basaltic or trap dykes, which will be more fully noticed in the following chapter. The faults containing clay, or sand, or fragments, have most probably been filled soon after they were opened, by the descent of water mixed with mud, sand, and fragments of stone, for I consider it almost certain, that most of the faults in coal strata were opened when the strata were submerged under the ocean, or in deep lakes. The faults sometimes cut the strata in the *line of dip*, sometimes in that of the *line of bearing*, (see p. 47,) and frequently in lines diagonal to both the dip and bearing of the strata, crossing the coal-fields in various directions, and intersecting each other. The intersection of faults in a coal-field, has been not unaptly compared by Mr. Williams, to the lines and intersections produced by the disruption of a sheet of ice, the lines of fracture crossing each other at different angles.* It is remarkable that Mr. Williams, who was a practical miner, takes no notice of the removal of the upraised strata in any part of his work. Indeed, he has fallen into some unaccountable mistakes respecting faults, for he says, broad faults seldom occasion much disturbance of the strata.

Dr. Buckland, in his valuable Bridgewater Treatise, also compares a coal-field intersected by dykes, to a broken sheet of ice, but he omits the extraordinary fact—the entire disappearance of the upraised strata.

---

* Williams's Mineral Kingdom.

"If (says he) we suppose a thick sheet of ice to be broken into fragments of irregular area, and these fragments again united, after receiving a slight degree of irregular inclination to the plane of the original sheet, the reunited fragments of ice will represent the appearance of the broken masses or sheets of coal measure we are describing. The intervening portions of more recent ice, by which they are held together, represent the clay and rubbish that fill the faults, and form the partition walls that insulate these adjacent portions of strata, which were originally formed, like the sheet of ice, in one continuous plane."*

A broken sheet of ice, subsequently united by fresh ice formed between the fractures, offers a good illustration of the *direction* of the faults intersecting coal strata, but the comparison holds good no farther; for two important conditions of the present coal-fields are left unnoticed in this comparison: first, the disappearance of the upraised portions of the beds; and, secondly, the present surface of a coal-field is not a plane, but rises into hills, and sinks into valleys, which bear no regular conformity to the inclination or elevation of the planes of the coal measures under the surface.

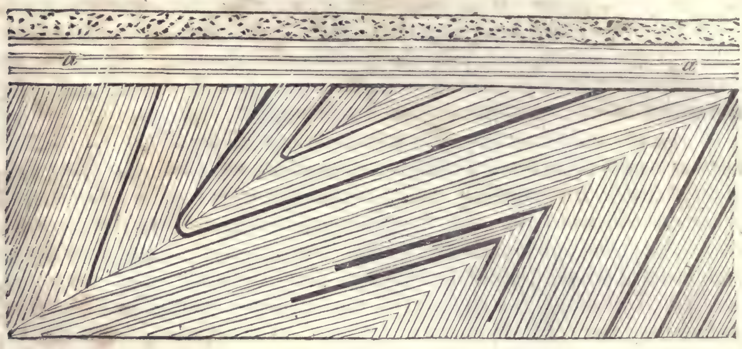
M. de la Beche says, "the line of faults runs in the direction of valleys." It may be so in some situations, but it is not the case in the coal districts, where faults have been most accurately traced. The lines of fault cross in all directions, running through the valleys transversely, and cutting through the hills on each side. Faults crossing valleys, and the rivers that run through them, if filled with basalt, often form fords and wears, which rise above the water, the basalt being harder than the strata which it intersects.

Besides the upheaving of the strata by faults vertically, they sometimes occasion a lateral displacement of the ground. Suppose a mass of basalt some hundred feet in thickness, to be suddenly forced through the strata along in a line running north or south. If the strata in such cases are not tilted up, they must be pushed in a direction east or west: but as the distant ground offers a resistance to such a motion, the strata must either be broken in a zigzag form, or be bent into curves. Instances of a zigzag position of the strata are sometimes met with in coal-fields. In the transition rocks, the beds are frequently folded into deep curves by a lateral force, which has been opposed by the resistance of adjacent rocks. The lateral protrusion of rocks sometimes displaces the adjacent beds over a great extent of country. A lateral displacement may also be caused by a sudden explosion or eruption of subterranean vapor, which may form vast chasms that may be afterwards filled with sand and fragments, by de-

* Bridgewater Treatise, p. 543.

scending water. In this manner, some of the wide faults in coal-fields appear to have been formed.

The most remarkable instance of coal strata being compressed in zigzag directions by a lateral force, that has hitherto been noticed, is at Anzim, near Valenciennes, in France. The annexed



section, given by M. Alexander Brongniart, will sufficiently explain the zigzag position of the coal strata. The upper secondary strata of chalk and marl, *a a*, which lie horizontally upon the zigzag beds, show that the upraised portion of the coal strata were removed, before the beds of chalk and marl were deposited.

Various instances of the overlapping and contortions of coal strata from lateral compression, occur in some of the coal-fields of England and Scotland. It is not, however, such lateral displacements or their causes, that form the subject of the present chapter. My object is, to direct the attention of the geologist to the vertical displacement, or upheaving of the coal strata by faults, and to the cause which has removed and carried away the upheaved strata, so completely, that no trace or vestige of them is visible on the surface. This fact is general, if not universal; it is admitted by Martin in his account of the great coal basin in South Wales; it is expressly stated by Mr. Mammott in his account of the faults in the Ashby-de-la-Zouch coal: it is mentioned by Mr. Farey in his account of the Derbyshire coal-fields, and he calls this disappearance of the upraised strata, the most surprising geological phenomenon.*

* Mr. Farey, after describing various cases of displacement of the strata by faults, adds, "I proceed to notice one of the most curious and important phenomena which the earth's surface presents, viz. that though the strata are, as it were, tossed and turned about in all degrees of the several cases above mentioned, as miners and colliers in particular can testify, yet that it is extremely rare to find a lifted edge or corner of strata standing up above the general surface, or occasioning a precipice or cliff."—*Farey's Derbyshire*, 123. In a note to the same passage he adds, that after a careful examination of the numerous cliffs and mural precipices in Derbyshire, and other rocky districts, he finds few, if any of them, "are owing to faults, but the matter has been excavated and carried off, which occasions the valley or plain at the bottom of the cliff."

I know of no instance that has fallen under my own observation, in any part of England and Wales, where the upraised strata in a coal-field are to be traced on the surface; and an eminent geologist, who has paid particular attention to the coal-fields in the western, midland, and northern districts, informs me, that he is not acquainted with any case, in which a terrace, formed by the upraising of the coal, can be seen; though he thinks he has heard of such instances, but he cannot recollect where.* This may suffice to show, that the disappearance of the upraised strata on one side of a fault, in coal-fields, is a general fact; though it is possible that some exceptions may be discovered.

No geologist, that I know of, has yet offered any explanation of the cause of this removal, except the vague supposition of diluvial currents, sweeping over the surface of the land. I am, however, inclined to believe, that a very simple and satisfactory explanation may be given without the aid of any hypothetical assumptions, but founded on admitted facts, which have not hitherto been sufficiently regarded.

The principal known geological facts relating to the coal formation, and the legitimate inductions from them, may, in connection with the present inquiry, be arranged under the following heads:

1. The series of strata in England and Wales, called collectively the great coal formation, commonly rests upon, or covers marine strata, chiefly the upper transition or mountain limestone.

2. The coal strata, to a vast depth, contain exclusively the remains of terrestrial or of fresh-water plants or animals; hence it may be inferred, that such strata are of fresh-water formation, though some of the lower beds in certain districts contain occasionally an intermixture of marine shells.

3. The coal strata appear generally to have been deposited in tranquil water; a few beds only present indications of having been transported from a distance by violent currents.

4. The coal strata, after their deposition in inland lakes or estuaries, subsided and were submerged in the ocean, and were covered in many parts by marine strata, particularly by the magnesian limestone, hereafter to be described.

5. The faults that dislocate the coal strata, were in some instances formed before the deposition of the upper marine strata: other faults were formed at a subsequent epoch, after the deposition of the marine strata; but in both cases it may be inferred, that the strata were beneath the sea, when the dislocation by faults took place.

---

* Professor Sedgwick.

6. At a later period, the coal strata and the upper marine limestone, by which they are in some parts covered, were raised above the level of the sea, and form a portion of the present land.

The first of these positions is admitted by all English geologists. The second, third, and fourth are as susceptible of proof, as any geological inductions from acknowledged facts. The fifth and sixth admit of direct proof.

In confirmation of the second position, if the constant occurrence of terrestrial and fresh-water organic remains exclusively, through a series of strata more than fifteen hundred feet in thickness, be not admitted as evidence of a fresh-water formation, we can have no proof of the fresh-water formation of the Wealden beds, or of any strata in the Paris basin or elsewhere.

In the Yorkshire and Derbyshire coal-fields there are proofs of a fresh-water formation, which the strata of the Paris basin do not afford. Extensive beds, called *muscle bind* occur in the middle of those coal-fields. They consist of dark indurated clay, filled with shells of fresh-water muscles (unios,) evidently occupying the native bed of mud or clay, in which the muscles lived and died. It is clear that these shells are in their natural position, and have not been drifted from a distance.* It would be impossible to bring more convincing evidence of a fresh-water formation; and when we find the strata, above and below the muscle bind, filled with remains of terrestrial or marsh plants exclusively, the fresh-water origin of such strata is also abundantly manifest. They were, it is highly probable, deposited in fresh-water lakes or estuaries, surrounded by the luxuriant vegetation of the ancient world. It is true that marine shells occur in some of the lower beds of the coal formation, in the West Riding of Yorkshire, and in Shropshire. The lowest beds of the Durham coal-field also sometimes alternate with limestone, supposed to be marine; in such cases we must admit, that the sea had occasional access to the lake or estuary in which the coal strata were deposited; but the upper strata, a thousand feet or more in thickness, contain only remains of terrestrial or fresh-water plants and animals. Nor are we yet certain, whether all the limestone strata alternating with the lowest coal beds, are marine or fresh-water.

The limestone below the coal strata at Burdie house near Edinburgh, supposed to be marine, is now stated to be a fresh-water formation, affording additional proof, that the coal strata above it, containing remains of land plants, are fresh-water formations.

---

* The bed of muscle bind, though extensively spread, can rarely be seen in the coal mines, except when it is cut through in sinking a shaft. Its outcrop is seldom noticeable on the surface, as, like other beds of indurated clay, it speedily disintegrates on exposure to the atmosphere. There is a fine outcrop of this bed on the side of a hill south of the river Calder, opposite to Shepley bridge, near Dewsbury, in the West Riding of Yorkshire, which I examined in 1814.

Perhaps, by farther investigation, it may be discovered that the limestone which is interstratified with the lowest beds of coal in the north of England, is, in some instances at least, fresh-water limestone.

If the strata of the great coal formation were deposited in lakes, the surface of these lakes must have generally been somewhat above the level of the sea. It is important to bear this in mind, because if admitted, it affords a decisive proof, that after the deposition of the coal strata, these strata and the circumjacent land subsided, and became deeply submerged under the ocean, where they remained, until they were covered with the thick beds of marine limestone, under which they are found in many parts of England. If we could prove that the coal strata were formed by materials drifted from the land into the sea, the necessity for this submergence would be avoided; but the exclusive remains of terrestrial and fresh-water plants and animals, indicate that this could not have been the case. A successive series of extremely thin strata of ironstone and clay, often contain perfect and delicate remains of plants or animals, which prove that they were deposited in tranquil water. They present a very different appearance from that which would have resulted from violent transporting causes. Indeed, if coal itself had been formed of the remains of marine vegetation, as was formerly maintained, we should have no need of admitting that coal districts had undergone any subsequent submersion. Thus, for instance, the mass of marine vegetation at the bottom of Weymouth bay might be supposed to represent the origin of a coal basin very well; and in passing over it in the year 1833, I could scarcely avoid the conclusion, that, in a future condition of our planet, this vegetation might form a coal stratum. We are however certain, that our present coal-fields are not formed of marine, but of terrestrial and fresh-water plants, analogous in many respects to the gigantic vegetation of tropical climates.

That the strata of the coal formation have been submerged under the ocean is completely established by the occurrence of marine beds over many of our coal-fields. It is further proved, that the faults which occur in coal-fields are of different ages: some of them dislocated the coal strata before the marine strata were deposited over them, for the faults do not disturb or displace the superincumbent beds: other faults are of a more recent date, and have cut through both the coal strata and the limestone which covers them.

Plate IV, fig. 4, may serve to elucidate what has been here advanced. Let A A represent a section of a portion of a coal-field, and B B strata of marine limestone, covering the coal strata unconformably; C C is a fault which has elevated the strata considerably on the side of the fault C C. It may be observed, that this

fault does not penetrate or cut through the marine limestone; it is therefore obvious, that the fault had disturbed the coal strata, before the strata of marine limestone were deposited, and that the limestone was not formed over the coal strata, until after all the broken strata raised above E E had been entirely removed; whereas the fault D D cuts through both the coal strata and the limestone, and was evidently formed after the latter was deposited. The dislocation of the limestone strata with those of the coal, by the fault D D, is not represented in this small section.

Practical miners, as well as geologists, have generally contemplated the removal of the strata, upraised by faults, as having taken place from the present surface of the land; and have regarded the strata as composed of hard beds of sandstone and shale: and have overlooked the original condition of these strata, before they had been raised above the level of the sea, and were indurated by drainage and pressure. In their original state, these beds were chiefly composed of mud and sand, saturated with water, and therefore could posess but little adhesion.

In reference to this inquiry, it is most important to bear in mind the original condition of the strata submerged under the ocean, or in deep lakes. We may form some idea what this condition was, by what we may sometimes observe at the present day in beds of calcareous tufa, at the bottom of lakes or rivers recently laid dry. Such beds often yield to the pressure of the finger, but when exposed to the atmosphere they harden, and form building stone. Even the strata of sandstone, in deep quarries, may often be crumbled within the hand; yet, after long exposure to the air, the same stone yields with difficulty to the chisel of the mason: indeed, the softening power of water is sometimes manifest even in rocks believed to be of igneous origin. I was informed, when in Cornwall, that in deep quarries of granite, the stone, when first raised, was easily sawn into slabs, a property which it soon lost when removed from the quarry.

The great difference in the softness of sandstone in its native bed, even many hundred feet above the level of the sea, from that of the same stone which has long been laid dry, is well known; but the difference must be much greater, in beds of stone that had never been above the level of the sea; such beds, saturated with moisture, could present little resistance to the agitation of the ocean, when they were suddenly raised above the lower submarine ground. The agitation of the sea, by the upheaving of a small island near Santorini, caused such an immense swell, at the distance of eighty miles, that the water rose forty five feet, and wrecked several vessels belonging to the Grand Seignor in the port of Candia. An account of the violent disturbance of the sea, off the coast of Chili, by an upheaving of the ground in 1836, will be subsequently noticed.

The fissures or rents that intersect coal strata, are often many miles in extent, and of vast width: the gaseous and aqueous vapor that first rushed through them, must have occasioned an agitation of the ocean inconceivably intense; and whether the land beneath were raised several hundred feet in a few hours, or a few days, the violence of the action and reaction of the water would sweep away the soft and yielding or crumbling upraised beds of the coal strata, which would offer less resistance, than a bank of sand or gravel, to the sudden rush of water from the breaking down of the side of a reservoir. Other forces were also in action. The enormous concussion by which the mass was driven upwards, must have shattered and broken the beds, when they were propelled above the bottom of the sea, and were suddenly removed from the lateral support of the beds with which they had been continuous; the force of gravity would further tend to level the upraised mass, and combine with the violent agitation of the water to break down and remove the yielding materials of which it was composed, and spread them over the bed of the ocean. The effect produced by the sudden upraising of the strata, by one fault only, has hitherto been considered; but it is highly probable, that several faults in the same coal-field were simultaneously opened; and the impetus given to submarine conflicting currents, driven in different directions, might increase the agitation of the water in an inconceivable degree, sufficient to break down and tear away even the hardest rocks, when suddenly dissevered from their native beds.

An effect so extensive as the entire disappearance of the broken and upraised strata, in all our coal districts that have been hitherto examined, could not be caused by local inundations sweeping over the surface of the land; for it may be asked, why should such inundations select for their theatre of action all the coal districts in Scotland, England, and Wales? Nor will a general deluge explain the disappearance of the upraised strata; because it can be proved, that the strata were broken and raised by faults at different and remote periods. A succession of general deluges would therefore be required; one, for instance, before the deposition of the marine limestone that covered the coal strata after their upraised beds had been removed, and another deluge would be required to carry away the strata raised by faults at a later epoch, after all the marine beds had been deposited.

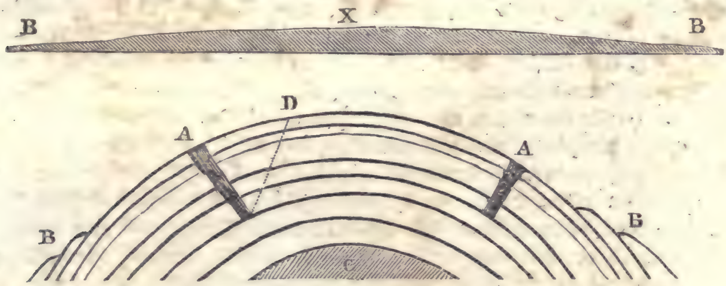
To conclude,—The disappearance of all the strata upraised by faults, in every known coal district, can I believe, be best explained by admitting the causes I have assigned—first, the soft and yielding condition of the submerged strata, that had never been indurated by drainage; and, secondly, the violent action of water upon them, when they were suddenly broken and forced upwards, but were still beneath the surface of the ocean.

The mountains and mountain ranges, that occur beyond the limits of the coal districts, may at first appear to oppose what has been stated respecting the disappearance of the upraised coal strata,—because such mountains and mountain ranges have, in most instances, been raised from beneath the ocean, and they remain, to form permanent and striking objects in the physical features of islands and continents: but we must bear in mind that the vast extent, magnitude, and elevation of great mountain ranges, remove them from the condition of the strata upraised by faults. The strata of the great coal formation seldom attain any very great elevation, the principal coal districts being situated near the feet of elevated mountain ranges; but these mountains, which form the highest portions of the globe, are chiefly composed of hard rocks more or less crystalline; they therefore offered a greater resistance to the action of water, than the coal strata; and, as they are many thousand feet above the surface of the sea, they became removed above the reach of its agency. But the great protection of mountain ranges or masses, I believe, consisted in their vast magnitude and extent. A chain of mountains, of a hundred miles in length, has generally a breadth of fifteen or twenty miles. A transverse section of the chain, when first rising under the sea, would form the low segment of a very broad arch, from which the water would gradually remove, and occasion a distant swell of the ocean, altogether unlike the agitation occasioned by the sudden fractures and uprising of smaller portions of the surface, which were probably as instantaneous, as the fractures and dislocations caused by earthquakes on land.*

The hills of the central range that runs through Derbyshire, and the West Riding of Yorkshire, and divides the eastern and western waters, are chiefly composed of hard gritstone and shale, which may be regarded as the beds on which the coal strata rest, at some distance from the central range. The average height of this central range is from 1200 to 1800 feet; its breadth from 12 to 15 miles; and its length, from the north of Derbyshire to Craven in Yorkshire, 70 miles. As the gritstone and shale contain abundant vegetable impressions, similar to those in the coal strata, of which they form the lowest beds, though no workable seams of coal occur in them, it may be fairly asked, Why has this range of hills escaped the destruction that swept away the upraised coal strata? To which we may reply, (as before stated,) they were

* The strata being upheaved on one side of a fault only, would, if the mass remained entire, (like Plate I, fig. 4,) be particularly exposed to the force of the agitated sea; whereas, had the strata been upheaved on both sides of the fault, they would form a hill, with strata sloping in opposite directions from the fault or anticlinal axis, as at Dudley Castle Hill. (Plate III, fig. 4, B.) The sloping sides would admit the water to pass over them with little resistance, and such hills might remain, when the strata upraised by faults were entirely removed.

protected by their magnitude and breadth: they form a very broad segment of a low arch, which has secured them from the destructive action of the sea; though it is probable that a considerable covering of the outer strata have in some parts been stripped off.



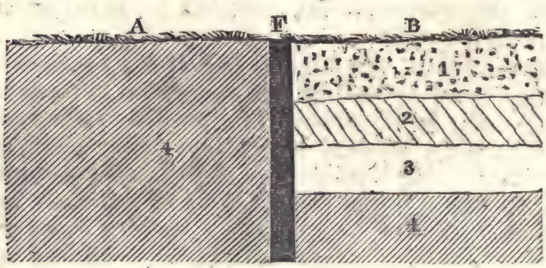
The annexed cut represents two transverse sections af this central range. In the lower section, for the sake of illustration, the height is represented as much greater than its due proportion to the breadth, which may here be about 12 miles from B to B. The upheaving cause, whether lava or vapor, is supposed to be situated at or under C: the strata over it are raised in a convex form, but are not dislocated or tilted up, as they are by faults. By the expansion of the surface, fissures would however be formed, descending to different depths, as at A A. These fissures afterwards might be widened by atmospheric agency, and form ravines or valleys, extending from A to the dotted line D. Such ravines, formed originally by fissures from the surface, will be noticed in a subsequent chapter; and it can in some instances be satisfactorily proved, that they were not produced by faults, or by rivers running through them.*

In the upper figure, the highest part of the transverse section at X is represented nearer the due proportion to the width B B; and it may easily be conceived, that such a comparatively low segment of an arch, when slowly and gradually raised from the bed of the sea, would occasion but little immediate agitation of the water, though it might cause a swell of the ocean in distant parts. Thus, extensive beds of soft or yielding strata might be elevated above the level of the sea, without suffering much denudation from the flux and reflux of the water. In this manner, also, lower hills and masses of considerable extent and breadth, composed either of coal strata or of soft calcareous secondary

* This section represents better the structure of a mountain mass, than that of a mountain range. The mountain called Masson, near Matlock, has such a structure; and the opening between A and the dotted line D represents the ravine between the High Tor and Masson. The subject will be resumed in the chapter, On the Elevation of Mountains.

strata, like chalk, may have been upheaved with little destruction of the beds, except what subsequently took place from atmospheric agency.

Whether the faults that intersect the secondary strata, at a distance from the coal districts, are as frequent as in coal-fields, may be doubted; these strata are rarely subjected to the exploration of the miner, and therefore comparatively few faults are discovered. Some faults are known to occur, and to have upraised the secondary strata in the same manner as those in the coal districts. Where faults do occur, the disappearance of the upraised strata is I believe general; and the same explanation of the cause of the disappearance, which has been applied to coal districts, will apply in this case also; as the beds have evidently been raised from the ocean, and subjected to the agitation occasioned by the sudden breaking and elevation of the ground, which formed at that period the bed of the sea. As the secondary strata remain to be described, farther remarks on the faults and denudations which occur in them, must at present be postponed. One circumstance, however, it will be proper to state. As the existence of faults, that do not appear on the surface, is seldom subjected to the proof of mining operations beyond the range of the mining districts, great mistakes have often been made by introducing faults, to explain difficulties, which the observer could not easily explain without them. On one side of a fault, a lower bed may be raised up, so as to breast against a bed much higher in the series; as in the following figure:—On the side B the beds 1, 2, 3, 4, are placed in their natural order over each other; but on the side of the fault A, the bed 4 is elevated and brought into the immediate level of the bed 1, separated only by the intervening fault F.



The beds 1 and 4 may, however, be brought into contact at the same level, without the intervention of any fault whatever. The strata that cover each other in a regular order of succession, as 1, 2, 3, 4, in the above section, are not always found together.

Sometimes the intermediate beds, as 2, 3, are wanting, and the upper bed 1 extends beyond the under ones, and comes in contact with the lowest bed 4, as represented in the following cut.

In this case a well, or excavation, sunk near to C, on the side of the section B, and another on the side A, would show an upper and lower bed brought to the same level; and hence the occurrence of a fault at C might erroneously be inferred, which had raised the bed 4 into contact with the bed 1. Such instances have not unfrequently induced geologists to interpolate faults, where, in reality, they did not occur.

Thus, in Dorsetshire, the green sand of the chalk formation, instead of resting upon the beds of oolite, extends beyond them, and covers the lower formations of lias or red marl. Fortunately, in this case, the cliffs on the coast present a perfect view of the true position of the strata, and show that the contact of the upper and lower beds is occasioned by the overlapping of the green sand.

Faults, filled with basalt, intersect all formations; and, from the extreme hardness of the stone, they may often be traced on the surface, when they cut through secondary strata, and thus furnish certain evidence of their occurrence. Faults, filled with clay or fragments, that have produced vast dislocations, often present no visible proof of their existence, except what can be discovered by penetrating the surface. When geologists of great experience and tact are engaged in investigating the structure of districts in which faults occur, the funds of scientific societies cannot be better expended, than by allowing such observers to call in the aid of working miners to sink pits and cut shafts through the supposed faults, thereby to ascertain their magnitude and contents, and the effects they have produced on the adjacent beds. An experienced geologist may often anticipate, with much probability, the nature and quality of a lower bed, not visible on the surface, but he cannot in all cases be expected to "see through a millstone (or any other bed of stone) a mile thick;" and the labors of working miners, well directed for a few days, might clear up doubts and difficulties, which cannot be removed by speculation or conjecture.

Faults, where their occurrence can be examined and fully ascertained, are manifestations of the extraordinary and violent action of internal causes, that cannot be mistaken by the geologist; they afford him as certain evidence of former terrestrial convulsions, as if he saw the earth opening and upheaving before his eyes.

CHAPTER X.

ON UNCONFORMABLE TRAP ROCKS AND BASALTIC DYKES.

Different Positions of Trap Rocks, as overlying, imbedded, or intersecting other Rocks.—Varieties of Trap Rocks.—Porphyry, Porphyritic Trap, Sienite, Greenstone, Clinkstone, Basalt, Amygdaloid, and Wacke.—Passage by Gradation into each other, and into Volcanic and Granitic Rocks.—Remarkable Instance of this Passage at Christiania in Norway.—Mountains of Porphyritic Trap and Clinkstone, with deep Craters.—High Stile, Cumberland; Cader Idris, Merionethshire.—Basaltic Dykes: Extent of the Cleveland Basalt Dyke.—Basaltic Dyke at the Clee Hills, in Shropshire.—On interstratified Basalt.—Remarks of Professor Sedgwick, on the Protrusion of Basalt between regular Strata.—On columnar Ranges of Basalt.—Organic Remains enveloped in Basalt.—Remarkable Basaltic Districts in Europe and America.—Experiments on Basalt.—Theory of Werner.—On the Conditions required for the Conversion of fluid Lava into compact Basalt.

The class of rocks about to be described in the present chapter, are extremely interesting to the geologist, as they present him with decided indications of their origin and mode of formation. They not only "reveal the secret of their birth," but, from their close alliance to many of the most ancient primary rocks, they disclose the operations by which a large portion of the earth's surface was consolidated, in the most remote geological epochs. Many of the trap rocks are so similar in structure and composition to the products of active volcanoes, and to beds of lava erupted in our times, that we may be said to see the very cause in operation, by which they were formed. Many of the trap rocks are also so similar in structure and composition to some of the most ancient primary rocks, that we can scarcely doubt respecting their having had the same origin, though they may have been consolidated under different degrees of heat or pressure, and with different attendant conditions. The name of Trap is derived from the Swedish word trappa, *a stair, and has been given to rocks of this class, because many of them divide into regular forms resembling the steps of stairs. Whether the term, in its literal sense, is well chosen as a generic name, may be doubted; but, taken metaphorically, it is extremely appropriate, as these rocks offer a series of gradations or steps, over which the geologist may safely travel in his speculations, from the lava of Etna, to the granite of the Alps.*

To obtain a correct knowledge of trap rocks, the student should first acquire a clear idea of their position. When primary and transition rocks form distinct beds, they are generally arranged conformably, or, in other words, the upper beds are moulded

upon the lower, and have the same elevations and depressions, as represented Plate III, fig. 1.

Trap rocks, on the contrary, are found on the surface in overlying, unconformable masses, or are imbedded in other rocks, or intersect them, rising like a wall, and breaking the continuity of the strata. Such walls are called dykes. Trap rocks that are imbedded, seldom preserve the form of regular strata for any great extent, but are extremely variable in their thickness; in many instances they appear to have been laterally protruded between regular strata. These different positions of trap rocks are represented Plate III, fig. 2. It is obvious that these unconformable rocks were formed at a period subsequent to that of the rocks which they cover or intersect.

As the mineral composition of trap rocks is nearly the same as that of rocks whose igneous origin is now undisputed, we can have little difficulty in admitting, that the overlying masses of trap have been poured over the surface of the conformable rocks in a state of fusion, like streams of lava from recent volcanoes; with this difference, that they were not erupted from one opening or crater, but from fissures of great width and many miles or leagues in extent, and that they were generally formed under the ocean. I say we can have little difficulty in admitting this, particularly as such rents or fissures, filled with similar matter to that of the overlying unconformable masses, are often discovered in their vicinity.

Trap rocks, however, are not unfrequently observed imbedded between strata of aqueous formation: here their origin appears more obscure. In many of these instances we may, without difficulty, admit that these trap rocks were formed by submarine volcanoes, which have poured beds of lava over the limestone; another bed of limestone may have been subsequently formed over the lava, and this limestone may also have been covered by the lava of a later eruption. In this manner the alternation of beds of basalt, or basaltic amygdaloid, with limestone in Derbyshire, may admit of a probable explanation. See Plate IV, fig. 5, *e e*, beds of trap between beds of mountain limestone, *a a*.

On the southern side of Etna there are several beds of undoubted lava alternating with limestone, as will be more fully stated hereafter. In some instances, however, the basalt or trap has evidently been protruded between the strata, after the period when the latter were deposited.

Before we proceed, it may be proper to remark, that there are certain porphyritic rocks bearing the general character of trap rocks, which are associated with slate rocks, and appear to pass by gradation into them. We cannot suppose that they have been erupted like lava, or protruded into the slate: they have probably been softened, by subterranean heat, with the slate *in situ;* but

from difference of composition, or different degrees of temperature, these beds may have had a greater facility in acquiring a porphyritic texture. A remarkable instance of the passage of slate into porphyry will be noticed hereafter.

If we sufficiently keep in view, that the crust of the globe with which we are acquainted does not exceed, in comparative thickness, that of a wafer to an artificial globe three feet in diameter; and that a very large portion of the globe is now or has in ancient times been rent or pierced through by active volcanoes, and that these volcanoes are not the seat of subterranean fire, but merely its chimneys, we shall have no difficulty in admitting, that extensive parts of the crust of the globe, far distant from any present volcanoes, may have been softened by internal heat, and the more fusible beds partly crystallized *in situ*, under the pressure of the ocean.

With respect to the overlying formations which pass by gradation into primary rocks (as some porphyries allied to volcanic rocks pass into granite,) this fact, so far from proving that the porphyry was not of igneous origin, tends strongly to confirm the hypothesis, which attributes an igneous formation to granite itself.* It is granted by the best observers, that a regular gradation may be traced between granite and the more ancient volcanic rocks, and that there is likewise a gradation between the products of ancient and recent volcanoes, of which we shall afterwards treat more fully.

It will be proper, before we proceed, to state the mineral composition of trap rocks. Felspar and hornblende, see Chap. III, constitute the principal ingredients of trap; in many trap rocks the mineral called augite is intermixed with felspar: indeed hornblende and augite resemble each other in chemical composition, and when uncrystallized, in external character also, and are now discovered to be different crystallizations of the same mineral. These compounds of felspar and hornblende, and felspar and augite, chiefly form the different rocks called greenstone, sienitic greenstone, basalt, clinkstone, pitchstone, wacke, and amygdaloid;

---

* However highly and justly distinguished many of the natural philosophers in France may be, it cannot be denied that they adhere more closely to theories once formed, and have a greater dread of thinking for themselves, than the philosophers of other countries. In confirmation of this, I shall translate an extract from M. Bonnard's *Aperçu Geognostique des Terrains*. It is truly amusing to see the alarm which he evinces, lest he should be compelled by stubborn facts to relinquish his cherished theories. "Another species of difficulty should prevent every prudent man (*esprit sage*) from attempting to explain the formation of these rocks of trachyte by any hypothesis founded on volcanic action; namely, the alarming extent of the consequences which may follow such an explication, relative to other rock formations, hitherto regarded as having a very different origin." With great respect for M. Bonnard, I would say, Let every *esprit sage* yield to the evidence which Nature presents, and leave consequences and theories to take care of themselves.

and also trap porphyry, and pitchstone porphyry. All these rocks may be regarded as different modes and combinations of felspar with hornblende or augite, differing chiefly in their internal structure.

When hornblende and felspar are intermixed, and have a granitic structure, they form what is generally called greenstone; and if the felspar be red, sienitic greenstone. When hornblende and felspar, or augite and felspar, are intimately combined and finely granular, they form basalt. The French geologists make a distinction between the basalt in which augite prevails, and that which is composed of felspar and hornblende; but it is admitted that where the structure is finely granular, or nearly compact, it is difficult, if not impossible, to distinguish them.

Basalt has a greenish or brownish black color, is difficult to break, and possesses a considerable degree of hardness; it will, however, yield to the point of a knife. On examination with a lens, even the more compact varieties of basalt are seen to be composed of minute crystalline grains; it frequently contains yellowish grains of a mineral called olivine; it contains also grains of iron sand, and a considerable portion of the black oxide of iron. Basalt is fusible into a black glass, and is magnetic. The iron which it contains passes into a further state of oxygenation when exposed to the air: hence basaltic rocks are generally covered with a reddish brown incrustation. Very black basalts are chiefly composed of augite.

Soft earthy basalt, intermixed with green earth, forms the rock called *wacke;* it has frequently a greenish color. When basalt or wacke contains rounded cavities, filled with zeolites, chalcedony, or calcareous spar, they form amygdaloid.* When the felspar greatly prevails, and the texture becomes nearly compact, basalt passes into the rock called phonolite or clinkstone, from its yielding a metallic sound when struck: the prevailing color is gray and greenish gray; it is fusible. Clinkstone, when it has a more earthy texture, passes into the rock called by English geologists claystone. Clinkstone often contains imbedded crystals of felspar, and then becomes a trap porphyry, which varies in color according to the prevailing ingredients of its base. Between felspar porphyry and trap porphyry there is an almost imperceptible transition; in the former, the base or paste is felspar, nearly pure. Some felspar porphyries pass gradually into granite, by an intermixture with quartz and mica.

Pitchstone has a blackish green, or a nearly black color; it is a semivitreous substance, having the lustre and appearance of pitch, and does in fact contain a portion of bitumen; its other

* The names Porphyry and Amygdaloid rather represent modes than substances, and convey no precise ideas, unless the base be specified.

constituent parts are the same as those of basalt; it approaches nearly to the black volcanic glass called obsidian, which is a lava suddenly refrigerated and perfectly vitrified. Pitchstone and obsidian are sometimes porphyritic. Hence we have on the one hand a series of rocks, (varying only in the increase of felspar, and state of induration,) from granular basalt to clinkstone and claystone, from clinkstone to trap porphyry, from trap porphyry to trachyte and felspar porphyry, and from felspar porphyry, with the further admixture of mica and quartz, to granitic porphyry and granite. On the other hand, from granitic greenstone there is a transition to sienite, and from sienite to true granite. Again: in the volcanic districts of Auvergne, we see scoriaceous lava become more compact, and at length pass into well characterized black basalt, with the columnar structure. In other situations, currents of lava form obsidian or volcanic glass; and between basalt, phonolite, and pitchstone, there is an almost imperceptible gradation.

Thus it may be seen that the whole family of trap rocks have on the one hand a close alliance with volcanic rocks; and on the other, with the more ancient rocks of porphyry and granite.

The gradation of trap rock, having in some parts a volcanic character, into true granite, has been described by Messrs. Hausmann and Von Buch as distinctly observable, and well marked, in a mountain in Christiania in Norway. The lower rocks are gneiss; over this occurs dark slate; and in the slate are several beds of blackish limestone, containing trilobites, and also orthoceratites several feet in length, with other marine organic remains. In some parts, a bed of gritstone or greywacke rests on the slate. The whole of these beds are covered by an enormous mass of porphyry, varying in thickness from 1600 to 2000 feet. The porphyry is of a smoke gray color, but it is reddish in some parts; it is compact, and moderately hard, and contains large crystals of white felspar, and crystals of quartz, epidote, hornblende, iron pyrites, and magnetic iron ore. In the lower part of the bed the porphyry becomes vesicular, and changes into an amygdaloidal basalt, containing crystals of augite. Near the sea, vast dykes of this porphyry, more than thirty yards in width, are seen cutting through the slate and beds of limestone. In another part of the country, at Holmestrand, the same mass of porphyry, covering beds of sandstone, is seen to pass in the lower part, by almost insensible gradations, into a hard fine-grained black basalt, containing brilliant crystals of augite: in the upper part of the bed, the porphyry passes into a sienite of singular beauty, containing crystals of zircon; and above this, the sienite passes into common granite. The dykes of porphyry cutting through the slate rocks, indicate the mode of formation of this porphyry, in a manner not to be mistaken by those who are acquainted with

the basaltic dykes in the northern parts of Great Britain. These dykes were doubtless the fissures through which this vast mass of porphyry had been poured out over the slate rocks, though Messrs. Hausmann and Von Buch describe them as veins descending from the porphyry. The reader may form a more distinct idea of the position of this porphyry and its relation to the subjacent rocks, which are intersected by dykes of the same porphyry, from Plate III, fig. 2, a.

Had M. Von Buch seen this remarkable mass of porphyry at Christiania, after his visit to the basaltic districts in England, he would, I am persuaded, have at once recognized the agency of subterranean fire in its formation. I saw this eminent geologist soon after his return from Cumberland and Westmoreland; and if I recollect distinctly his opinion respecting the mountains of porphyritic trap and clinkstone intermixed with slate in these counties, it was, that they bore a striking resemblance to some of the most ancient volcanic mountains in Auvergne, and that, like them, they had been softened *in situ*, and elevated by subterranean heat. The operation of igneous agency in these mountains is much less evident than in the porphyry of Norway, if the description given of it be correct. The only porphyry occurring in unconformable beds that I have seen in Cumberland or Westmoreland, covers part of a mountain of coarse slate, on the right hand side of the road going from Kendal to the granite mountain of Shap. It forms a nearly horizontal bed composed of red felspar, which has an earthy texture, and contains crystals or grains of quartz; it is what the French would denominate a red trachyte. Considerable fragments of the same rock are scattered in the adjacent valleys, proving that at a former period, this porphyry was more extensively spread over that district. A red porphyritic felspar, nearly similar in composition and appearance, forms the top of the mountain called Red Pike above the Lake of Buttermere in Cumberland. Closely adjacent to Red Pike, and forming part of the same ridge, is the mountain called High Stile. Between the summits of these mountains is a deep crater with a small lake or tarn at the bottom of it: the sides of this crater are very steep; it is partly surrounded by rude columns of clinkstone on one side; the porphyritic felspar of Red Pike forms the other side. The clinkstone has a smooth conchoidal fracture and a greenish gray color; it contains small crystals of felspar, and is slightly translucent on the edges and very fusible; it is highly sonorous when struck with a hammer. The height of High Stile is 2100 feet above the level of the sea; the depth of the crater is about 500 feet; the side nearest the lake of Buttermere, by which alone it can be entered, is partly open. Situated as it is on the summit of a very narrow steep mountain range, that divides the valley of Buttermere from Ennerdale, no conceivable

operation of water could have scooped out the crater, and the bed of the lake within it.

Though the rocks which surround this crater are closely allied to volcanic rocks, and have probably been subjected to the agency of subterranean fire, yet the crater is not composed of lava and scoriæ, like that of modern volcanoes. Cader Idris, in Merionethshire, is similar in composition and structure to High Stile; it has also a deep crater, with a small lake at the bottom. The opinion of Von Buch, that some volcanic mountains have been upheaved bodily in a solid mass, would, if admitted, elucidate the formation of these mountains: the craters may not have ejected lava, but may have served for vents to the elastic fluids or steam, that, combined with heat, were the agents by which the mountains were upheaved; or we may suppose the craters to be formed by a partial sinking down of the summits, when the mountains were still softened by heat. It may, however, deserve the future inquiry of geologists, whether the red felspathic trachyte on one side of the crater of High Stile, which forms Red Pike, and extends over the mountain, may not once have flowed as lava.

Many mountains in Cumberland and Westmoreland are composed of porphyritic trap, passing into clinkstone. In a deep ravine of Swarthfell in Cumberland, opposite the seat of J. Marshall, Esq., the mountain, which is here composed of clinkstone, presents the columnar structure on a magnificent scale; the columns are slightly bent and inclined.

Porphyry, from an intermixture with hornblende, frequently passes into sienite; when this is the case, the latter rock generally forms the upper part of the mass. Porphyry and basalt, in enormous masses, often cover the primary mountains in the Andes. According to Humboldt, "they are arranged in regular columns, which strike the eye of the traveller like immense castles lifted into the sky." Some geologists describe four formations of porphyry; but this division is purely theoretical, as those who admit it, agree that the different formations of porphyry frequently pass into each other; and, from the evident connection of porphyry and basaltic with igneous rocks, it naturally follows, that such transitions must take place. Many porphyritic rocks may be regarded as more ancient than basaltic rocks, as porphyry frequently occurs intermixed with, or covering transition rocks, and basalt is most commonly associated with the secondary strata. I am informed by Professor Sedgwick, that the porphyry of the Cheviot Hills has produced frequent and great dislocations of the beds in its vicinity. We have few instances beside, that I am acquainted with, in England or Wales, of eruptions of well defined porphyry; they are not uncommon in Scotland and in the Alps. We shall proceed to describe the phenomena pre-

sented by trap rocks, of which there are numerous striking examples in Great Britain and Ireland.

In describing the phenomena presented by any of the trap rocks, we describe those peculiar to every member of the trap family. Were it allowed to express a geological fact in familiar terms, it might be said, that all the members of this family give indications of a fiery character, and of having been troublesome neighbors to the adjacent rocks, disturbing them, and even changing their nature when they are closely associated. Beside occurring in overlying unconformable masses, all trap rocks, with porphyry, which may be placed at their head, are occasionally found intersecting other rocks like vertical walls. It has been before stated, that these vertical walls are called *dykes*. The dykes that intersect coal strata have been noticed in the preceding chapters; other phenomena presented by basaltic or trap rocks and dykes, which indicate their igneous origin, remain to be described.

Trap dykes and basaltic dykes are generally harder than the rocks that they intersect; and when the latter are partly decomposed, often remain, forming vast walls of stone that rise above the surface of the ground. There are walls of this kind in the counties of Northumberland and Durham, running along the country several miles. Dykes also extend into the sea, and form reefs of rocks; and when they cross the beds of rivers, they form fords, and sometimes hold up the water and occasion cascades, of which there are numerous instances on the river Tees. In the interior of North America, basaltic walls were discovered by Messrs. Lewis and Clark, of great extent; the walls were composed of columns of basalt, arranged horizontally, and were at first supposed to be artificial constructions. Where basaltic dykes are of considerable thickness, the hardness of the stone varies in different parts; sometimes the inner parts are harder, and sometimes softer, than the outer, the substance in the dyke being divided by seams or partings. This may be distinctly seen at Coaly Hill, near Newcastle-upon-Tyne, where a large basalt, or whin dyke, cuts through the coal strata, and rises to the surface. The stone being hard, is quarried for the roads along a line of several hundred yards, forming a deep trench sufficiently wide to admit a cart road through the quarry, between the sides of the dyke.

The basalt of the dyke is insersected by fissures, and is divided into variously shaped masses. In one part of the dyke it appears to graduate into an indurated ferruginous clay, which is in some places divided into minute, well defined pentagonal prisms. The dyke had charred the coal on each side of it, and rendered it soft and sooty; to use the language of a quarry man, who was working in the dyke when I visited the place in 1813, "it had burned the coal wherever it had touched it." The same dyke extends from the sea to the western side of the county of Northumberland; its termination in that direction is unknown.

The longest mineral dyke that has been traced in England may be called the Cleveland Basalt Dyke: it extends from the western side of Durham to Barwick, in Yorkshire; it crosses the river Tees at this place, and proceeds in a waving line through the Cleveland Hills in the East Riding of Yorkshire, to the sea between Scarborough and Whitby. It rises to the surface, and is quarried, in many parts of its course, for stone to lay upon the roads. From Barwick-on-the-Tees it may be traced, in an easterly direction, near the villages of Stanton, Newby, Nunthorp, and Ayton. At Langbath-ridge a quarry is worked in it; it passes south of the remarkable hill called Roseberry Toppin, near Stokesly, and from thence by Lansdale to Kilsdale; it may be seen on the surface nearly all the way in the above track. From Kildare it passes to Denbigh Dale end, and through the village of Egton-bridge, and hence over Leace-ridge through Gothland, crossing the turnpike road from Whitby to Pickering near the seven mile stone, at a place called Sillow Cross, on a high moor. I examined it at this place, where it is quarried for the roads, and is about ten yards wide. From hence it may be traced to Blea Hill, near Harwood Dale, in a line towards the sea, near which it is covered with alluvial soil; but there can be little doubt that it extends into the German ocean. It is a dark greyish brown basalt, which turns brown on exposure to the atmosphere; it is the principal material for mending the roads in the district called Cleveland. I am indebted to Mr. Bird, of Whitby, for an account of the situations where it may be seen on the surface. He has traced it through Yorkshire and Durham; in the latter county it cuts through the coal strata. Professor Sedgwick, in a valuable paper on the Trap Dykes of Yorkshire and Durham, published since this account of the Cleveland Basalt Dyke was originally written, says, that the continuity of this dyke with others west of the Tees, is not fully ascertained: he thinks the length of the dyke may be estimated at from fifty to sixty miles. The course of this dyke is marked in the geological map of England, Plate IV. By consulting the large maps of England, the course may be distinctly traced: drawing a line in the direction from Cockfield in the county of Durham to Barwick-on-the-Tees, and extending the line east and west, it will pass near all the places above mentioned. In some situations where the angle in which this dyke cuts the strata can be ascertained, it is about eighty degrees.

A circumstance attending this and other extensive dykes, which has not, I believe, been hitherto regarded by geologists, completely invalidates the theory, that dykes were originally open fissures, formed by the drying or shrinking in of the rocks. This dyke, in its course, intersects very different formations, viz. the transition or metalliferous limestone, the coal district, and the

upper secondary strata of lias and oolite. The different organic remains in these formations, as well as their position, prove that they were consolidated at distant periods of time. Indeed, the geologists who maintain that dykes were formed as before described, are ready to admit the distant eras of these formations. The transition or metalliferous limestone, and the lower strata, must have been completely consolidated long before the upper secondary strata were deposited; and the causes which might dispose the upper strata to shrink in, cannot be supposed to act on the lower rocks. It is also to be remarked, that in the lower rocks, situated to the west, the breadth of this dyke is more than twenty yards; but at Sillow Cross, where I measured it, it is not more than ten yards: this dyke must, therefore, become wider as it descends. It must also have been filled with basalt at the time of its formation, otherwise it would have contained numerous fragments of the rocks which it intersects.

The effects of this basaltic dyke on the different rocks through which it passes, are truly deserving notice. When it comes in contact with limestone, the limestone is often found granular and crystalline; a fact, the geological importance of which will be subsequently adverted to. Where it crosses the coal strata, and comes in contact with the seams of coal, the substance of the coal is for several feet converted into soot. At a greater distance from the basalt, the coal is reduced to a coke or cinder, which burns without smoke, and with a clear and durable heat. At the distance of fifty feet from the dyke, the coal is found in its natural, unaltered state. It is particularly remarkable, that the roof immediately over the coal is lined with bright crystals of sulphur. In some situations in the same county, the shale, in contiguity with basaltic dykes, is converted into flinty slate or jasper. and the sandstone is changed to a brick color. There is another great basaltic dyke in the same district, which crosses the western extremity of Durham from Allenheads to Burtreeford, on the river Tees, hence called the Burtreeford Dyke. It throws down the strata on the west side of it, one hundred and sixty yards.

Dykes, being generally impervious to water, they obstruct its passage along the porous strata, and occasion it to rise; hence it frequently happens, that numerous springs make their appearance along the course of a dyke, by which it may be detected, when there is no other indication of it visible on the surface. Some thermal springs rise from the vicinity of basaltic dykes.

Basaltic dykes intersect both primary and secondary rocks, but they every where present indications of their action on the adjacent rocks. At Nigg, near Aberdeen, I examined a basaltic dyke on the coast, which intersects a rock composed of gneiss; the dyke is about thirty feet in width. Where the basalt is in contact with the gneiss, it becomes nearly compact, and approaches

to the character of hornstone, and the gneiss has a red and burnt appearance, approaching in its nature to porphyry. It is probable that the action of the basalt on the sides of the gneiss rock had softened it, and rendered it more liable to disintegrate than the other parts; for the sea has here made an indentation inland, forming a deep narrow ravine or bay, with a lofty wall of basalt running through it. The wall of basalt completely divides the bay, and the sea enters on both sides of the basalt. It has been before observed, that when basaltic dykes extend into the sea, they form reefs of rocks and small islands. These basaltic walls, whether rising above the surface of the country, or extending into the sea, serve to mark the destruction of the land; for we are certain that these walls of mineral matter, were at one period supported on each side by rocks or strata which they have intersected, but which are now worn away. The Cleveland basalt dyke, it has been stated, cuts through the transition limestone; the coal strata, and the upper secondary strata, comprising a part of the oolite formation.

The constant occurrence of dykes in basaltic districts, gives a high degree of probability to the opinion, that overlying unconformable trap rocks, have been erupted through these dykes in a melted state like lava, and have been poured over the surface of the ground.

There are, however, some districts in which basaltic beds occur, where no connection between these beds and basaltic dykes have yet been discovered; probably because due investigation had never taken place. "The Titterstone Clee hill is the highest mountain in Shropshire. Its summit is covered with basalt, provincially called Jew-stone: detached blocks of basalt are scattered over its sides. A mass of basalt, from fifty to sixty feet in thickness, is concealed under the surface. Around the hill are several small coal-fields, arranged in basin-shaped concavities. I visited this hill in 1811. The existence of basaltic blocks and beds in such an elevated situation, remote from other basaltic districts, excited my surprise; but I found, from the evidence of respectable miners, that a vast fissure or dyke, more than one hundred yards wide, filled with basalt, intersected the hill, and cut through the small coal-fields. It rises from an unknown depth: where it comes in contact with the coal, it has injured its quality, and reduced it to a sooty state. There can scarcely be a doubt, that this basalt, like fluid lava, forced a passage for its eruption, where the basaltic dyke at present rises near the surface."—*Introduction to Geology*, 1st edit. 1813, p. 124.*

* The account of this dyke, given in the first and second editions, having been doubted by a geologist who had never visited the place, it was omitted in the third and fourth editions. The leading facts above stated have since been satisfactorily

A similar instance of a bed of basalt, formed by the expansion of a dyke, is described by Professor Sedgwick in the Transactions of the Cambridge Philosophical Society. In this instance, both the dyke and its expansion are exposed to view in a stone quarry. "In the quarries now excavating near Bolam, the vertical dyke is unusually contracted in its dimensions; but, on reaching the surface, it undergoes a great lateral extension, especially on the southwest side, so that the works are conducted, in a perpendicular face of columnar trap, more than two hundred feet wide." The drawing below, (copied from that of Professor Sedgwick,) will give a distinct idea of this mode of formation. It may be proper to observe, that the dyke is a continuation of the Cleveland basalt dyke, which I have before described. The horizontal measures through which it passes are coal measures.

There can be no more doubt respecting the cap or expansion of basalt having been erupted through the dyke, than there can be of the origin of a bed of lava, which may be traced to the mouth of an adjacent volcano.

Beds of trap or basalt, interstratified with other rocks, have given rise to much speculation respecting their origin: that such beds are not unfrequent in the coal measures, is a fact well known to miners in the north of England. From the great hardness of trap beds, (provincially called beds of whinstone,) they increase the difficulty and expense of sinking shafts. These interstratified masses have been frequently described as regular measures or strata. There is a thick bed of trap in some of the coal-fields in Durham, called the Great Whinstone Sill; the word *Sill* be-

---

ascertained, and the occurrence of the dyke having been claimed as a new discovery, the author was advised to introduce his original description in the present edition. The plate which accompanied it is omitted, but the section of a basaltic dyke in Cleveland, by Professor Sedgwick, (as above,) will sufficiently represent the structure and expansion of the basaltic dyke at the Clee Hills.

ing used for stratum by Mr. Westgarth Forster, in his section of these strata, published in 1809. This bed or mass of whinstone, though described by Mr. Forster as a regular stratum with the series of strata in which it occurs, is admitted to vary in thickness from twelve to sixty yards. It is found at a great depth in some mines, in other situations it rises to the surface. An objection has been suggested, if this bed be of igneous origin, in what manner did it become interstratified with beds that are evidently aqueous depositions? Those who first raised this objection could scarcely have kept in mind, that every bed in the whole series of the coal measures was once the upper surface of the solid ground, whether that surface was covered with water, or was dry. An eruption of lava might therefore flow over any particular bed in the whole series, and this lava might become covered by subsequent aqueous depositions. But there is another mode in which the lava might be introduced among the strata at a later period; it might be protruded laterally between them. That such lateral protrusions have actually taken place in some instances, is proved by Dr. MacCulloch's observations on the coast of Scotland, where trap may be seen forming beds between strata of sandstone, then suddenly cutting through the upper strata and forming other beds above. See Plate III, fig. 3, where strata of sandstone are intersected vertically by a dyke of basalt, and laterally by nearly horizontal beds of the same basalt. Professor Sedgwick has bestowed much labor in investigating the true position of the Great Whinstone Sill, and its relations to the different strata in its vicinity, and has given a very luminous and satisfactory description of the remarkable phenomena which it presents, proving unanswerably the igneous origin of this rock.

It would be doing great injustice to this valuable paper, to attempt an abridgment of the detail of interesting facts and arguments which it contains: I shall briefly recapitulate some of the observations. The whin sill is not a regular bed interposed between the same strata in different parts of its range, but it cuts through or overlies very different strata. It has had an extraordinary effect in converting beds of shale, on which it lies, into a porous slag; and where the whin sill comes in contact with limestone, the limestone is converted into a dull white granular and crystalline mass. (Query, Dolomite?)

This conversion takes place not only in the subjacent limestone, but sometimes on the limestone which covers the whin sill,—a fact deserving particular attention, as it indicates that the whin sill was protruded between the beds of limestone, otherwise it could scarcely have produced any chemical or mechanical change on the upper bed of limestone. In some parts, beds of limestone are seen bent upwards and imbedded in the whin sill:

indeed Professor Sedgwick thinks it probable, that the whin sill was produced by a lateral injection of volcanic matter, in a state of igneous fusion.

The beds of trap or toadstone, imbedded in the mountain limestone of Derbyshire, were supposed by Mr. Whitehurst to have been protruded or driven, in a melted state, between the strata: this opinion was chiefly founded on the belief that the metallic veins, which cut through the limestone, 1, 2, 3, do not pass into the toadstone, (see Plate IV, fig. 5,) they were therefore supposed to have been broken through, when the latter beds were protruded. It has, however, since been discovered, that the veins do often pass into the toadstone, though they seldom bear ore in this rock; hence the conclusion of Mr. Whitehurst was deprived of its main support. Subsequently, Mr. Farey, in his survey of Derbyshire, misled by an attachment to theory, described the beds of toadstone as regular strata, preserving their thickness and continuity through the Peak of Derbyshire. This is by no means the case; the beds of toadstone are extremely variable in their thickness and order of succession, and the intermixture of green-earth, toadstone, and limestone, near the junction of toadstone with the limestone beds, certainly favors Mr. Whitehurst's original theory of protrusion; but this protrusion took place before the formation of metallic veins, and might be the cause of those fissures in which the veins were formed. It is not improbable that some of the more regular beds of toadstone may have flowed as lava. Professor Sedgwick justly observes, "that our reluctance to admit the theory of protrusion arises from the difficulty of conceiving any powers in nature adequate to produce such an effect. But all the phenomena of Geology show, that the great disturbing forces by which the crust of the globe has been modified, acted in former times with incomparably more energy than they do at present. Volcanic forces are now employed in lifting a column of melted lava to the lip of a crater. The same kind of forces, acting with more energy and through a wider region, may in the early history of the globe, have been employed in lifting islands and even continents from the bottom of the ocean. During an operation like this, the elastic forces, acting from below, may often have driven masses of fluid lava among the superincumbent strata; and, in every case, the lava would naturally be propelled through those portions which were most easily penetrated—the lateral must, at every point, have been equal to the vertical pressure. The expansive forces may not at any point have been able to drive a column of lava through all the solid unbroken beds, but the lateral forces may have driven a portion of the fluid between the partings of two horizontal beds; and when a penetration of this kind was once effected, the lava would act like a wedge to mechanical advantage, and rush in an horizontal

stream to a distance proportioned to the elastic forces which were in action."*

The formation of basaltic dykes is sufficiently explained by what takes place in the vicinity of volcanoes. Before the confined vapor that afterwards issues through the crater finds a vent there, the surface of the ground in the vicinity of the volcano is frequently upheaved, and fissures of great extent are made, into which melted lava is sometimes forced, which, on cooling, forms a wall or dyke, in every respect similar to a basaltic dyke. During an eruption of Vesuvius, in 1794, a rent of this kind was formed near the bottom of the mountain, 2375 feet in length and 237 feet in breadth, which became filled with compact lava. Rents or fissures of some miles in length have been opened on the sides of Etna. There is abundant evidence to prove, that most basaltic rocks were erupted under the pressure of the ocean; and it is probably owing to circumstances attending their refrigeration, that they have frequently a columnar structure.

The occurrence of thick beds of basalt, divided into regular pentagonal or hexagonal columns, and disposed in ranges of vast extent and height, could not fail to arrest the attention of the most careless observer, and give rise to speculations respecting their origin and formation. Basaltic columns are frequently seen in countries that are the seat of volcanic fires, but they occur also in countries very remote from any active volcanoes. The theories respecting their formation will be subsequently adverted to.

Few countries in the world present more magnificent basaltic columnar ranges than the north part of Ireland, and some of the Hebrides: probably these are connected under the ocean, and have had the same origin.

The Giant's Causeway constitutes a small part of a vast basaltic range, along the north coast of Ireland, in the county of Antrim. The part originally called the Causeway, is a range of basaltic columns, projecting from the base of a steep cliff, some hundred feet into the sea; but the Giant's Causeway is more generally understood to comprise all the lofty ranges of columnar basalt, extending from the two promontories of Bengore and Fairhead, about eight miles. The cliffs or capes consist of various ranges of pillars and horizontal beds, which rise from the sea to the height of five hundred feet. From their elevation and ab-

* It may be proper to mention, that Mr. William Hutton, in a paper read to the Geological Society of London, maintains, that the great bed of basalt in Northumberland, called the whinstone sill, was deposited over the limestone beds on which it rests, and not protruded laterally between them: though he allows with Professor Sedgwick, that the basaltic beds in Teesdale were protruded in the manner before described. Mr. Hutton admits, that in some instances the limestone over the basalt had suffered the same effects of igneous action as the limestone below it. These instances, I think, afford satisfactory evidence, that the basalt was protruded between the beds of limestone.

ruptness they are very conspicuous, and form a pile of natural architecture, in which the regularity of art appears united with the wild grandeur and magnificence of nature. Many of the columns at Fairhead are from one hundred and fifty to two hundred feet in height, and five feet in diameter. At the base, along the shore, is a wild waste of rocky fragments, that have fallen from the cliffs.

At the part properly called the Causeway, the columns rarely exceed one foot in diameter, and thirty feet in height. They are sharply defined, and the columns are divided into blocks or prisms of one foot or more in length, which fit neatly into each other, like a ball and socket. The basalt is close grained, but the upper joint of each prism is cellular. The columns have most frequently five or six sides; some have seven or eight sides, and others not more than three.

At the cliff, called the Pleaskin, the two upper beds of columnar basalt are the most perfect. The uppermost, at the height of 400 feet above the sea, is covered by a bed of amorphous basalt, about ten feet in thickness. The bed of basalt beneath, consists of a regular range of columns, about sixty feet in height. This magnificent colonnade rests upon an irregular bed of vesicular basalt; below this is a range of sharply defined columns, from forty to fifty feet in height. This range rests on a bed of red ferruginous clay or ochre, from which the cliff slopes to the sea, for the space of two hundred feet. Though only two complete ranges of pillars are visible in any of the promontories, yet Dr. Hamilton observes, that there may be many more in succession at various depths.

The columns at Fairhead are not articulated like those of the Giant's Causeway. The blocks of which they are composed are of great length, and are flat at their extremities. It is remarkable that these basaltic ranges are intersected by narrow dykes of basalt, which consist of basaltic prisms, lying horizontally. The basalt of Antrim, appears to extend along the coast, and inland about forty miles; it is twenty miles in breadth.

Basaltic dykes, of great magnitude and length, range east and west in the province of Connaught, and are probably connected with the basalt of Antrim. The basaltic formation extends northward to the island of Rathlin, and it may be conjectured that it ranges under the sea, and is connected with the basaltic islands in the Hebrides.

Ranges of columnar basalt have been discovered in the interior of Antrim. In some parts the columns rest on a bed of lignite or wood coal, which is extremely hard and brittle, where it is in contact with the basalt. Most probably the coal was submerged under the ocean, when the bed of basalt covered it. Messrs. Buckland and Conybeare, published a very instructive account of

the geology of this part of Ireland, in the 4th volume of the Geological Transactions, from which we first learned the true character of the secondary strata (associated with the basalt,) which are lias and chalk. In one part, a dyke of basalt passes through the chalk, which becomes crystallized on each side of the dyke.

The basaltic columns of the Island of Staffa are too well known to require a description; but, according to Dr. MacCulloch, the columns which form the lofty promontory called the Scuire of Egg, another of the Hebrides, exceed in grandeur and in picturesque effect those of Staffa: they are formed of black pitchstone, containing crystals of glossy felspar. "The promontory rests on a bed of compact grey limestone, approaching to a stone marl. This bed, which is three or four feet thick, rests on a still lower bed of hard reddish stone. Masses of bituminized wood, penetrated with carbonate of lime, are found in the marl stratum, not at all flattened. Portions of trunks of trees, retaining their original shape, but petrified (silicified,) are found in the same stratum ; the rifts are filled with chalcedony, approaching in aspect to semi-opal. The columns on this island are both perpendicular and inclined, and some of them are bent or curved."

In various parts of Scotland and the Hebrides, the tendency to a columnar arrangement in the basaltic rocks may be distinctly seen : it is obscurely developed in the basalt of Arthur's Seat near Edinburgh. The basalt of this hill appears identical with some of the volcanic mountains I examined in Auvergne, paticularly near the summit of Montadoux, a mountain near Clermont.

In England the columnar structure of some of the basaltic and trap rocks is observable in the northern counties, particularly on the banks of the river Tees, and at Swarthfell near Ulswater. In some of the basaltic hills near Dudley, the columnar structure is developed, but the columns are not separated and well defined. Prismatic blocks of sienite are scattered over a hill of sienite called Markfield Knowl, at Charnwood Forest in Leicestershire.

Columns of porphyritic trap or greenstone occur in groups, on the northern side of Cader Idris in Merionethshire. One of these columnar groups is represented Plate V, fig. 1 ; the outline of the columns was taken with a camera lucida by Henry Strutt, Esq. of Derby, and cannot fail to be correct ; the figure is introduced, to show the relative magnitude of the columns.

Rocks of trap and basalt, both in solid beds, and also arranged in columns like those of Staffa, were observed by Sir G. Mackenzie on the coast of Iceland, and also in the interior ; the lower parts of the beds and columns contained scoriæ and slags, and empty cavities. A successive range of beds of basalt was also observed alternating with beds of tufa, the lower parts of which presented the same appearance of the action of fire.

From the situation of these rocks, and from the existence of submarine volcanoes near Iceland, Sir G. Mackenzie conceives, that these beds of basalt were formed under the sea by the ejection of lava, which, flowing over the moist submarine ground, would confine a portion of water beneath the melted mass: this water would be converted into elastic vapor, or steam, which would endeavor to expand: but where the superincumbent pressure of the ocean, or the tenacity of the lava, prevented its escape, it would be compressed, and form cavities, or air bubles, at the bottom of the melted mass. In other instances, where the fluidity of the lava permitted the steam from below to escape through it, the mass would be compact, and form solid basalt, or greenstone. It might sometimes happen, that water would be inclosed in the cavities of the mass, which is found to be the case in some basalt rocks. Thus, according to the different circumstances of pressure from the depth of the ocean, and from the tenacity of the melted mass, Sir G. Mackenzie supposes that porous and vesicular lava, or compact basalt, might be formed from the same eruption; or the mass might be porous below, and compact above.

As Iceland is at present the seat of active volcanoes, and as submarine volcanoes are forming rocks near the shores of that island, Sir George Mackenzie's explanation of the causes which have produced the various appearances in the basaltic ranges of that island, seems highly probable.

In Sicily, the connection of basaltic with volcanic rocks, has been clearly established by Ferrara, professor of natural philosophy at Catania.

Beside the columnar form common to many basaltic rocks, basalt sometimes presents a globular structure, with concentric laminæ: such globular masses consist of hard basalt, and are often imbedded in softer basalt or wacke.

Wacke or earthy basalt is frequently cellular, and the cavities are generally filled with nodules of agate, or with zeolite or calcareous spar. The agates are composed of concentric layers, and have apparently been formed by siliceous infiltration, depositing successive coats within each other, until the cavity is filled up. Basaltic rocks of this kind are called amygdaloids. The Hill of Kinnoul, in the vicinity of Perth, is formed of basaltic amygdaloid, containing agate nodules in great abundance, of various dimensions and beautifully striped. At Woodford Bridge, in Gloucestershire, there is a low rock of amygdaloidal wacke, which is much intermixed with green earth, and has, in some parts, a saponaceous feel; the agates which it contains are decomposing, and the inner concentric layers are separated from each other, and present the appearance of edges of folded paper, with small interstices between each. I examined this singular rock in 1816; it was then quarried for stone to mend the roads. In some parts

of the rocks I found masses of corallite of considerable size, enveloped in the basaltic amygdaloid. I found also, in this rock, well defined groups of prehnite, which was not then known to be an English mineral: it has since been discovered in the basalt of Staffordshire.

The occurrence of organic remains enveloped in basalt, of which there are various instances, may admit of an easy explanation, if we allow that basalt has once flowed like lava at the bottom of the ocean. Modern lavas, often envelop bones and other substances that they meet with in their course.

Having before described the phenomena presented by imbedded trap, which indicate that, in some instances, it has been protruded between regular strata laterally, it will be useful to cite an instructive example of beds of trap alternating with limestone, by successive deposition, which is stated by Dr. Daubeny, the present chemical professor at Oxford, in an interesting sketch of the Geology of Sicily. The facts seem clearly to ascertain, that beds of amygdaloidal trap, alternating with beds of limestone, have, in that island at least, been formed by successive currents of lava flowing over the bed of the sea, at intervals of time so distant, as to allow the deposition or formation of a bed of limestone, over each current of lava. A considerable district near Lentini, on the southern side of Mount Etna, and also a part of the island near Cape Passero, are composed of alternating beds of lava, with tertiary limestone abounding with organic remains of madreporites, nummulites, cerithea, and the remarkable fossil called the Hippurite. Santa Venera, the loftiest mountain in the south of the island, is capped with cellular lava; beneath it is a bed of limestone with minute shells; at a lower level, towards Lentini, there is a second bed of volcanic matter similar to the first; and two other similar alternations of beds of limestone and lava, occur still lower down. Dr. Daubeny says that the cellular and semivitreous aspect of many of the volcanic beds associated with the beds of limestone, precludes all doubt respecting the manner of their formation: the character of other portions present strong analogies to rocks of the trap family; "they are compact, and have a stony fracture; they contain crystals of olivine, and the cavities are filled with calcareous spar or zeolites, like the amygdaloids of more ancient strata. In some of the beds, a tendency to a columnar arrangement is discernible."

This account of Dr. Daubeny's affords additional proof of the close connection of ancient volcanic rocks with trap rocks,—may we not add, of their perfect identity? It is beside highly illustrative of the alternation of the beds of basaltic amygdaloid, with beds of limestone in other situations. But in both instances, we must admit, that the beds were formed under the ocean, before the present islands and continents had emerged from the watery abyss. With respect to Etna, the alternation of lava and lime-

stone affords decisive evidence, that this mountain was upheaved from the ocean, though its height may have been augmented by eruptions of lava, since the period of its first elevation.

Having described the principal phenomena attending trap rocks, whether occurring in dykes, in unconformable masses, or interstratified with other rocks, it may be proper to mention certain experiments that have been made, to elucidate the formation of basaltic rocks. All trap rocks are fusible, and most of them form a blackish green glass after melting: hence it was inferred, that trap rocks had never been in a state of fusion; for if they had, they would have been rendered vitreous. Sir James Hall, however, reflecting on the long period of refrigeration that vast masses of melted rock would necessarily require, before they were cooled to the common temperature of the earth, was induced to make experiments on lava and basalt; from which it was ascertained, that if a small portion of liquid lava were suddenly cooled, it formed a black glass, as was well known to be the case with basalt, but if the process of cooling were slow, both melted lava and basalt became stone. When the glass which had been formed by sudden cooling was melted again, and suffered to cool very gradually, it lost its vitreous character, and was converted into a substance resembling basalt.

Mr. Gregory Watt made some experiments on the fusion and refrigeration of basalt, in one of his father's furnaces, which throw much additional light on the formation of the globular and columnar structure of basaltic rocks. He fused seven hundred weight of the Dudley basalt called Rowley ragg, and kept it in the furnace several days after the fire was reduced. It melted into a dark colored glass, with less heat than was necessary to melt the same quantity of pig iron. In this glass, small globules were formed, which afterwards disappeared; and as the cooling proceeded, the mass was changed from a vitreous to a stony substance: other globes were again formed within the stony mass, which continued to enlarge until their sides touched and pressed against each other, by which pressure the globes formed polygonal prisms. If part of the mass were cooled before the globular structure was destroyed, these globes were harder than the surrounding stone, and broke in concentric layers. In this manner the balls of basalt and porphyry which fall out of decomposing rocks were probably formed; they derived their superior hardness from the crystalline arrangement of the particles, when in a melted state. When these globes were enlarged by a continuation of the same process, they might press on each other, and form prisms. The upper prisms pressing by their weight upon the lower, might form concavities or sockets, into which they would sink, and remain joined together or articulated. Such is frequently the structure of basaltic columns.

Another experiment, made by Sir James Hall, on the crystallization of common limestone by heat, and its conversion into marble, tends to elucidate the effects produced by basaltic rocks, on limestone and chalk before mentioned. Dr. Hutton had advanced the opinion, that beds of limestone were formed of the shells and exuviæ of marine animals, which had been melted by central fire, and crystallized. The first part of this theory respecting the entire formation of calcareous rocks from animal remains, it is not necessary to discuss at present: that a considerable portion of many limestone rocks were so formed, cannot be denied. It was, however, objected to this theory, that the well known action of fire on limestone rocks would expel the fixed air, and render them soft and pulverulent. To this objection it was replied, that as the action of central heat on beds of marine shells took place under the ocean, the pressure of the water would prevent the escape of the fixed air, and would probably render the calcareous earth more fusible. This answer was regarded as a mere hypothesis for some time, but Sir James Hall determined to try its validity by experiments. Having calculated the resistance which a column of water fifteen hundred feet, or any given depth, would present to the escape of fixed air, he enclosed a quantity of powdered chalk in a gun barrel, and confined it in such a manner as to present an equal degree of resistance. He subjected the powdered chalk thus confined to the action of a furnace; after some time it was drawn out and cooled, and was found converted into crystalline limestone or marble. In one instance, where the chalk enclosed a shell, the shell had acquired a crystalline texture, without losing its form. Hence in situations where chalk or earthy limestone are found to have a crystalline texture, when in contiguity with trap rocks, we may infer, with a high degree of probability, that the limestone had been fused by the trap.

A recapitulation of the facts and experiments which prove the igneous origin of trap rocks, would afford a mass of evidence which might convince the most sceptical inquirer; but such a recapitulation is needless, as in many situations undoubted currents of lava pass into trap rocks, and we have ocular demonstration of the fact.

The reason why geologists were so long opposed to the igneous origin of basaltic rocks, may partly be explained by the attachment to received theories, and partly by the reluctance to admit a condition of our planet, so remote from present experience. It was thought an ample claim on our credulity, when we were required to believe, that all the habitable parts of the globe had been for ages submerged in the ocean, without requiring the further belief, that countries now remote from active volcanoes, had been repeatedly subject to the agency of subterranean fire.

Yet both these positions must be granted, if we will allow a legitimate induction from established facts.

The advocates of the aqueous origin of basaltic rocks, while they advanced theories, which made claims upon our faith, equally unsupported by present experience, failed entirely in their attempts to explain the causes of existing phenomena in a satisfactory manner. The theory of Werner was for some time zealously supported, and particularly the least tenable part of it,—the formation of basaltic rocks by a second rising of the ocean, which deposited them on the summits of elevated mountains.—It may be proper to give a brief account of this part of the Wernerian system, before it entirely sinks into oblivion.

According to the theory of Werner, all the superficial parts of the globe were once in a state of aqueous solution, from which the materials were at first separated by chemical deposition in a crystalline state, and formed a thick mass of granite round the globe. Upon granite the primary rocks were successively deposited, forming layers over each other like the coats of an onion. Over these again were laid the transition rocks; and next, the earthy stratified rocks. Each of these layers was supposed to encircle the globe, or to be an universal formation. While this process was going on, the waters were gradually retiring, and became turbid; hence the materials which they deposited to form the upper strata, were more earthy than those of the primary rocks; they were also intermixed with fragments of the rocks previously formed. According to this system, mountains and valleys were caused by the original inequality of the nucleus of the earth. So far the parts of Werner's theory are consistent; and we have a world ready made, in which every thing might be supposed to remain quiet; but—*non sic Fata sinunt:*—Neptune, ashamed of his late retreat, and indignant at his confinement in such narrow limits, calls the infernal deities to his assistance, and, rising in his might, once more takes possession of the globe. He covers it with the depurgations of his turbid waves: but again he is compelled, slowly and reluctantly, to retire from the field, leaving behind him the basaltic rocks, the monuments of his triumph and his shame. Such is in substance the theory of Werner, respecting the origin of all the superincumbent rocks of basalt and trap. They are also, according to this theory, universal formations. It is scarcely possible for the human mind to invent a system more repugnant to existing facts. Were basaltic rocks deposited from a solution which covered the globe after the formation of secondary strata, as Werner supposes, every part of the dry land, and every valley, must have been incrusted or filled with basalt,—it would be the prevailing rock of every district. On the contrary, basalt exists only in particular situations, forming dykes, and overlying masses or beds of limited extent: nor do fragments of basalt occur in any quan-

tity, to warrant the belief that it was ever formed universally over the globe. What is here said of basalt, applies equally to all unconformable rocks of porphyry, and the other trap rocks. Nothing but the obscure language in which this doctrine of Werner was advanced, could have prevented its absurdity from being instantly perceived and acknowledged.

Before concluding the present chapter, it will be useful to advert to an inquiry which the geological student may probably make. The component parts of dark colored lava and basalt being the same, and the formation of both by igneous eruption being admitted, what were the conditions under which the erupted mass was formed into compact basalt in some situations, and in others into cellular lava?

According to Von Buch and M. Elie de Beaumont, lava in a fluid state cannot form thick regular compact beds of basalt, unless the surface of the ground over which it flows, (whether on land or under the ocean,) be horizontal, or nearly so; for it is evident, that a current of fluid lava would descend to the bottom, if it flowed over a declivity, and only a small part, which became congealed during the descent, would adhere to the surface. For the conversion of fluid lava into compact basalt, it is required that the lava should be spread over a level surface, or be collected in hollows or basins, where, like water, it would remain stagnant, until it became consolidated into a compact bed. The inference from this is important; for if all beds of basalt that are highly inclined were deposited and consolidated on a nearly level surface, it follows, that they must have been since elevated by some upbearing force; and that their inclined position could not be the original one, at the period of their consolidation.

If a current of lava be descending during its refrigeration, the adhesiveness of the particles will be more or less destroyed by the movement, and the stone will become porous or cellular. The cells so formed are often found to be elongated in the direction of the descending current. Thus the difference between cellular lava and compact basalt, depends on the state of motion or rest, under which the lava is consolidated.

It was supposed, a few years since, that there were no basaltic rocks in the United States of North America; but Professor Silliman, in the seventeenth volume of the *American Journal of Science*, has given a very clear description of a basaltic range, which divides the State of Massachusetts, extending one hundred and twenty miles in length, and from three to twenty miles in breadth.

Messrs. Jackson and Alger, of Boston, New England, have recently published, "*Remarks on the Mineralogy and Geology of Nova Scotia*," with colored plates, representing the immense ranges of basaltic rocks on the shores of that peninsula.

CHAPTER XI.

A RETROSPECTIVE VIEW OF CERTAIN GEOLOGICAL FACTS AND INFERENCES.—RELATIVE AGES OF MOUNTAIN RANGES.—PRELIMINARY OBSERVATIONS ON THE SECONDARY STRATA.

Before we proceed to the Upper Secondary Rocks, it may be useful to review some of the leading facts stated in the preceding chapters, and to notice certain inquiries, which may naturally present themselves to the mind of the geological student. It appears from an examination of the crust of the globe, wherever it has been scientifically explored, that there is an order of succession or superposition in the rocks of every country, which may often be traced over a considerable extent; and that in countries very remote from each other, an approximation to a similar order is observable, except in one class of rocks which are protruded irregularly, and cover other rocks without any determinate order of succession, as described in the last chapter. The succession of the several *classes* of rock,—the primary, transition, secondary, and tertiary,—may be regarded as certain, where they occur together. Nor is the regularity of this succession on a large scale invalidated by some apparent deviations.

Granite being of igneous formation, may, in a few situations, have been protruded through the upper rocks, and poured over them; but in such rare cases it will, I believe, be found, that the protruded granite issued from veins that intersect the older granite itself. Mountains of granite, composed of nearly vertical beds several thousand feet in height, like those of Mont Blanc, and its attendant aiguilles, could not have been upraised in a fluid state, but in a solid mass bodily.

In every continent or large island that has yet been examined, granite is the lowest or fundamental rock, and may therefore be called primary. Gneiss and mica slate are only different modes of granite, and may be found sometimes alternating with it.

The chemical composition of all these rocks is very nearly the same, nor is it very different from that of the older slates: silex forms, on the average, three fourths of their constituent parts, and alumine about one sixth or one eighth,—the proportions of the remaining parts cannot greatly affect the condition of the mass; and it is to the circumstances (whatever they may be) which have occasioned a more or less rapid consolidation of the parts, that we ought, probably, to attribute the formation of granite in one part of a mountain, and of gneiss, mica slate, or

slate in another, and the re-appearance of granite above the latter rocks.

The succession of the different members of any one class of rocks, is by no means so definite as that of the classes themselves. Many beds, common in one country, cannot be discovered in another, and hence it may be difficult to determine what part of a series they occupy.

It is easy to conceive, that the cause or causes, whatever they may be, which have formed certain rocks, have been limited in the extent of their action, as we know to be frequently the case on a smaller scale, where a stratum of sandstone, &c. after preserving its regular thickness for several miles, becomes gradually narrower, till at length, in the language of the miner, it *wedges out*, and the stratum above and beneath come in immediate contact. In other instances, the rock which is interposed between two well known and identical rocks in distant districts, is not the same in both: this may be frequently observed among the secondary strata, which will next be described. In such cases, the different rocks that occur in the same geological position, have been called equivalents of each other. An instance mentioned in a preceding chapter, may serve to explain what is meant by a geological equivalent. In the beds of transition limestone at Llanymynah, which are very regularly stratified, one stratum of the best limestone suddenly terminates, and its place is supplied by a bed of marl of equal thickness; in the same manner as we might suppose part of a course of bricks to be taken out of a wall, and its place filled up with clay; the clay would be the equivalent of the course of bricks.

On observing that the succession of strata in formations of the same class is not invariably the same in distant countries, an inquiry naturally suggests itself: are the similar rock formations in distant parts of the world contemporaneous? or were rocks of different classes forming at the same period? Is the granite of England, for instance, more or less ancient than the granite of the Alps? or, are the secondary strata of one country as old as the primitive rocks of another?

Were it not for the organic remains in different rocks, we could not (as Cuvier has well observed) be certain, that all rock formations were not contemporaneous. With respect to those rocks which contain no organic remains, and under which there are no other beds containing organic remains, we cannot ascertain whether they were contemporaneous, or formed at different and distant epochs. The beds of granite, which are nearly vertical in mountain ranges, must have acquired a considerable degree of solidity, before the period when the beds were raised: but if we date their age from the epoch of their elevation, we shall be obliged to admit the different ages of granite mountains, and that the

granite of Charnwood Forest is more ancient than that of the Alps. Of this we have as direct proof as we could possibly require. In the Alps, the beds of the upper secondary strata, analogous to our magnesian limestone, lias, and oolite, where they approach the central granitic range, are raised into nearly a vertical position conformable to that of the beds of granite, and they must all have been elevated at the same time. See Plate II, fig. 2, where the relative situation of the beds of upper secondary limestone is represented, *a a*.*

At Charnwood Forest, in Leicestershire, very highly inclined beds of granitic and slate rocks are covered with horizontal beds of the upper secondary strata, analogous to those in the Alps. See Plate II, fig. 4, *a a*. Now it is evident, that the beds of granitic and slate rocks were raised, before the horizontal strata were deposited upon them. Hence we attain the knowledge of an interesting fact in the natural history of our island: its beds of primitive and transition rocks were raised before the beds in the mountains of Savoy and Switzerland; nor can this conclusion be invalidated, unless we admit, what would be contrary to analogy, that secondary strata, possessing the same geological relations, and the same organic remains, were formed at different epochs. I have cited the Charnwood Forest Hills, because there the proof is more direct and palpable than at the Malvern Hills or elsewhere; for the horizontal upper secondary strata, may be seen resting immediately on highly inclined beds of granitic and schistose rocks.

The horizontal beds resting on the Charnwood Forest granite and slate, are composed of sandstone, (a part of the red marl and sandstone formation,) and at a little distance, the sandstone is covered by strata of lias limestone, *e*, which determines its relative age. In some parts, the sandstone strata also cover the coal strata; the latter, *d d*, rise very abruptly as they approach the granite in the north. At the Vosges mountains in France, the same red marl and sandstone, associated with lias, covers the granite and coal strata unconformably.

When M. Daubuisson published his *Traité de Geognosie*, in 1819, he asserted, that the beds of granite in the Alps were raised into their present vertical or highly inclined position, soon after their original formation. I visited the Alps in the two following years, and the appearances presented by the secondary strata, compelled me to draw a very different inference respecting the period when the beds of granite were elevated, which I stated in the second volume of my Travels, published in 1823.

---

* The calcareous mountains in the outer ranges of the Alps, removed from the central granite, are often bent into arches, as represented in Plate II, fig. 2, x, y, z. Such beds, of course, cannot be conformable to those nearer the granite.

"One important fact may be deduced from these elevated beds of puddingstone, sandstone, and other strata, comparatively modern, ranging conformably with beds of granite and gneiss; viz. that the beds of granite did not acquire their elevated position, till after the formation of the secondary strata. In England, the elevation of the beds of granite was anterior to the deposition of the upper strata, consisting of magnesian limestone, lias limestone, oolite, chalk, and the intervening sandstones; for all these strata lie nearly flat, over the edges of the inclined under strata. On the contrary, in Savoy, strata of similar formations occur nearly vertical, and frequently conformable to the range and dip of the granitic formations. These facts would prove, that the causes which have elevated granite, have acted at different epochs on various parts of the globe, unless we are prepared to admit, that similar calcareous formations, containing similar organic remains, were not contemporaneous in different countries."

In the latter part of the same volume, I further stated, that as some of the strata on the Diableret mountains in the Vallais contain, at the height of seven thousand feet, fossils similar to those of the tertiary strata in the Paris Basin, it was more reasonable to believe that they had been raised since their deposition, than that fresh-water formations had covered any part of the earth at such a vast elevation; and hence we may infer, that the epoch when the granite of the Alps was raised, is comparatively recent.*

When M. Daubuisson published his *Geognosie*, both he, and almost all French geologists, adopted the theory of Werner, respecting the formation of granite prior to all other rocks: if, therefore, the elevation of its beds took place soon after its original formation, this elevation preceded the deposition of the secondary strata by many geological ages, and could have had no effect on the position of beds which did not then exist. My views with respect to the different ages of granitic ranges, and the discovery of the true secondary character of the calcareous mountains in the Tarentaise, have since been brought forward by some French geologists, as their original discoveries. My observations were made in the year 1820, at which time they would have been warmly opposed in France; and the answer to them would have been, "Have we not had an *Ecole de Mines* at Moutiers in the centre of the Tarentaise, where some of our first chemists and geologists resided for a long time? we must there-

* Since the author published his opinion in 1823, respecting the recent elevation of the Alps, founded on an attentive examination of the structure of the Pennine and Bernese Alps, M. Von Buch, M. L. Elie de Beaumont, and M. Andre de Luc, of Geneva, have advanced similar opinions, and stated that the elevation of those mountains took place after the formation of the tertiary strata.

fore know the true character of the country, better than any occasional visiter."

It is not, however, certain, that the elevation of beds of granite, or other primary rocks, might not take place deep under the ocean, and a far more extensive elevating power, may, at a later period, have been required to raise them above the waves, until they formed islands and continents. Indeed, such must have been the case where primary rocks are covered with nearly horizontal strata of marine or aqueous formation. Even the nearly horizontal beds of red marl, that cover the elevated beds of granite on Charnwood Forest, must have been formed or deposited under water: the whole, therefore, have been raised together, when that part of England emerged from the ocean; unless the red marl was formed in a mediterranean lake or sea, surrounded by distant high ground. Adopting this view of the subject, though we may be certain that the beds of granite in England were elevated before those of the Alps, it does not follow that England must necessarily have been dry land before the Alps of Savoy. Since, therefore, the elevation of the beds in mountain ranges, may have preceded their final emergence above the ocean, this consideration deprives the investigation into the relative antiquity of the elevation of the beds in mountain ranges, of much of its value.

Before proceeding to describe the secondary and tertiary formations, I shall offer some preliminary observations, connected with the inquiry respecting the relative age of the different beds. Where a similarity of mineral character, and a similar association with other beds, is observed in different districts, we may sometimes infer, that their origin was cotemporaneous; but when the organic remains are also the same in both, we attain a full conviction of the fact.

It will not be denied, that the chalk and oolite in Yorkshire were cotemporaneous with certain parts of the chalk and oolite formations, in the southern and western counties. In the same manner we may admit, that the chalk, and oolite, and lias, on the opposite side of the Channel, in France, are cotemporaneous with similar formations in England, with which they preserve an identity of mineralogical and zoological characters. Having once traced these formations to the north of France, we may admit their identity with similar formations, preserving the same identity of character through many of the inland departments of France, and to the Salins, at the foot of the Jura range. Over so large an extent of country, we may expect to find, as we do in distant districts in England, that certain parts of a series which occur in a certain formation in one place, are wanting in another. In France, some beds occur, under the lias, for instance, which

have not hitherto been found in Great Britain: but making allowance for such partial variations, we cannot hesitate to admit the identity of the formations in both countries, and also their identity of age.

When we enter the Jura, or the great calcareous ranges of the Alps, the enormous thickness of the beds, which are frequently inaccessible, and the indurated and subcrystalline texture which they often assume, present considerable difficulties if we attempt to identify them with well known formations. Much confusion and contrariety may be observed in the classification of these rocks by different geologists; but this has partly arisen from the observers not being thoroughly acquainted with the formations with which they were to make the comparison, and partly from the vague and contradictory use of the terms Alpine limestone (*calcaire Alpin*) and Jura limestone (*calcaire de Jura.*) There is, however, in some parts of these mountains, both an identity of mineral and of zoological characters, with some of the formations in the upper secondary strata in England. A thick bed of blue lias, filled with the *Gryphæa arcuata*, in the mountains on the lake of Annecy, and fragments of oolite, like that of Gloucestershire, from the top of Mont Grenier, near Chamberry, left me no doubt of the identity of the formations of England, France, and Savoy; and no reason can be assigned, which might lead us to infer, that the similar formations in each country were not cotemporaneous. With respect to very remote countries, or the countries in opposite hemispheres, we have as yet few data to determine whether there be a similarity of fossil remains, which can identify formations that may appear analogous, or even whether such a similarity could identify them, when they occur in very different latitudes, and under very different degrees of temperature.

There is another circumstance, independent of climate or remote distance, that may have occasioned a change in the genera, and even in the orders and classes of animals, whose remains are found in similar strata. The ocean may have been much deeper in one part than in another, not very remote, and the deepest bed of the ocean might support genera of pelagian animals;* while a more shallow adjacent part might be tenanted by different genera, and even different orders and classes of animals, whose organization fitted them for moving near the surface of the water. The transition strata were probably formed under a great depth of the sea; and few of the animals, whose remains are found in these strata, possessed the power of locomotion in an eminent degree. The animals possessing this

* Pelagian animals, so called by naturalists, because they live in deep seas.

power were mollusca.* Their shells were divided into numerous chambers or cells; a tube, called a siphunculus, passes through all the cells; and by this tube it was supposed, that the animals were enabled to exhaust the water, and rise to the surface from great depths. The shells of many of the species of these animals were internal, like the bone of the sepia or cuttle-fish. They had heads surrounded by feelers, and large eyes; they had also beaks like those of the parrot. The feelers which surrounded the head, (see Plate VIII, fig. 1,) served them for seizing their prey, and for swimming or walking at the bottom of the sea. They swam with their heads behind them; and when they walked, their heads were downward. There are only two known genera of chambered animals of this class inhabiting the present seas; the Nautilus and the Spirula. See Plate VIII, figs. 3 and 11. The ammonite, of which there are numerous fossil species, was also spiral. The other fossil chambered shells are either straight or slightly curved. These shells were internal; and it is probable that the animals to which they belonged had greater facility of rising and descending than those in spiral shells.

The animals of this class, having heads and various senses, seem to rank high in the scale of sentient organic beings; but they are not numerous, till we rise into the secondary strata, above the coal formation.

Very few spiral unchambered shells occur in the transition rocks;† for these animals crawl on their bellies, like the snail, and do not seem fitted to live in deep water, unless, like the Helix Janthina, which nearly resembles the snail, and lives in the Southern ocean, they had little appendages, like bladders, which enabled them to rise to the surface. Univalve unchambered spiral shells become numerous in the upper strata, probably from the circumstance, that these strata were deposited under shallower seas.

With respect to that class of the testaceous Mollusca which did not enjoy the privilege of having heads and eyes, their motives for travelling, whether for pleasure or necessity, must have been few indeed; and they may be supposed to enjoy life as well in the deepest recesses of the ocean, as nearer its surface. The tenants of bivalve shells, called by Cuvier *Acephales*,‡ have, however, some power of locomotion, which they effect, some

---

* Called by Cuvier, *Cephalopodes*. For a brief account of the principal fossil species of this order, see the preliminary observations in the present volume. A very interesting description of fossil cephalopodes is given in Buckland, B. T. vol. i. pp. 303—386.

† All unchambered spiral shells were occupied by animals which had an organ of motion placed under the body, as in snails: they had heads, and are called by Cuvier, *Gasteropodes*.

‡ Acephales—having no heads.

by thrusting out a membrane called a foot, and with it, they also attach themselves to rocks or other bodies, by a number of filaments, called the Byssus, which they can remove at pleasure; others have two tubes, with which they force out water with considerable violence, and impel themselves in an opposite direction, and others again, by a strong muscular action in opening and shutting their shells, can jump twelve inches at one leap.

All these modes of motion, however, though sufficient for the wants of the animal, are very limited in their operation, and are equally adapted for animals in deep or shallow seas, in rivers or lakes: accordingly we find numerous testaceous mollusca of this class, both in the transition, the secondary, and the tertiary strata, and in our present seas and lakes, and at various depths.

CHAPTER XII.

TABULAR ARRANGEMENT OF SECONDARY STRATA.—NEW RED SANDSTONE.—MAGNESIAN LIMESTONE.—ROCK SALT AND GYPSUM.

Relative Geological Position of the Secondary Class of Rocks.—Their Mineral and Zoological Characters.—Tabular Arrangement.—New Red Sandstone and Red Marl.—Upper, Middle, and lower Beds, chiefly formed of the Fragments of more ancient Rocks, broken by some great Convulsion.—Lowest Red Sandstone, or Roth-todte Liegende of the German Geologists.—Separated from the Middle Beds, by Beds of Magnesian Limestone.—Middle and Upper Beds of Red Sandstone and Marl; their Accordance with those of France and Germany.—Muschel Kalk wanting in England.—Magnesian Limestone of the Northern Counties.—Gypsum accompanying Rock Salt originally Anhydrous.—Rock Salt Deposits, in different Formations.—Copious Brine Springs, above and below the Coal Strata in the United States.—Observations and Queries.

Secondary rock formations comprise all the regular strata that cover the transition rocks and coal measures, and terminate with chalk. Their mineral characters may be briefly described, as they occur in England, France, and part of Germany. They consist of vast depositions of sandstone and conglomerate beds, and of numerous calcareous beds, separated by beds of clay and sand. The limestones are less crystalline, and more soft and earthy than transition or mountain limestone. They abound in remains of testaceous animals, which are chiefly marine shells; but remains of fresh-water animals occur in some of the secondary beds; and parts of fossil terrestrial vegetables are also sometimes found, proving the existence of dry land at the period when the strata were deposited. Secondary strata cover a large portion of the habitable globe, and are the immediate subsoil of the most fertile districts in England, and various parts of Europe. No beds of good mineral coal are found in any part of the secondary series of strata, above the regular coal measures in England; but some beds of imperfect coal, and wood coal, occur in the secondary formations: and this is also the case in similar formations on the Continent. Neither metallic veins nor metallic beds deserving notice (except of iron ores) occur in this class of rocks; nor do they afford any of the rare species of crystallized minerals. Rock salt and gypsum are the most valuable minerals found in the secondary strata; and it is from them that all the important salt springs issue. Some of the rocks in this class yield useful materials for architecture; but the stone is generally soft and perishable. To the rocks of this class, Werner gave the name of flœtz or flat rocks, because, in the northern parts of Europe, they are generally arranged in nearly horizontal

strata: but this character is altogether inapplicable to the secondary strata in the outer ranges of the Alps, and in the Jura chain, where they may be observed bent in every possible direction, and sometimes nearly vertical. In these mountain ranges, the mineral characters of the upper secondary limestones also frequently undergo a considerable change, and become indurated and crystalline, like transition limestones.

It has been stated in the preceding chapters, that the coal strata, which are interposed between the transition rocks and the secondary strata, contain almost exclusively the organic remains of terrestrial and lacustrine or marsh plants, while the fossils in the lower or transition class, belong almost exclusively to marine animals. Another great change appears to have taken place in the condition of our planet after the deposition of the coal strata, for the upper secondary strata contain principally the remains of marine animals. It is in the strata belonging to this class, that the bones and entire skeletons of enormous reptiles are first discovered. It is, however, truly remarkable, that throughout the whole séries of the upper secondary strata, no bones of mammiferous land quadrupeds have yet been found; the strata at Stonesfield alone present a solitary exception.

In England, the order of succession of the upper secondary rocks may be more distinctly ascertained, than in any other country that has yet been examined. I shall therefore describe them as they occur in our own country, with references to foreign localities, where the same beds or formations are well identified with the English strata. Geologists on the continent, and particularly in France, had, till very recently, no accurate knowledge respecting several of these formations; and their classifications of them were vague and contradictory. More attention, however, has very lately been directed to this part of the geology of France; and the clear accounts which have been published by M. Elie de Beaumont in particular, of some of these formations, remove much of the obscurity which prevailed respecting them, and prove, in a satisfactory manner, the great similarity which may be observed, in the secondary formations of England and France.

In the following tabular arrangement of the secondary formations, above the transition and coal formations, I have not thought it expedient to introduce the minor subordinate beds in each formation. It may be frequently observed, that particular beds which occur in one part of a formation, and are considerably developed, cannot be traced even into an adjacent district, or they vary so much in thickness and mineral characters, as scarcely to be recognized. If we take an extensive formation, like the oolites, as an example, it is not possible to assign any one part of the range, as affording a correct type of all the series in distant, or even in neighboring parts of the range, though we may trace

a general resemblance in all the principal beds; and this I hold to be amply sufficient for every valuable purpose in geology.

SECONDARY FORMATIONS,

above the transition and regular coal formations, and terminating with chalk.

1. RED SANDSTONE AND MARL WITH MAGNESIAN LIMESTONE.

a Lower beds of new red sandstone.	a *Grès rouge ancien et roth-todte liegende. Grès des vosges ?**
b Magnesian limestone.	b *Zetchstein et rauche wacke.*
c Upper red sandstone.	c *Grès bigarré.*
d (Muschel kalk wanting in England.)	d *Muschel kalk.*
e Red marl with fibrous gypsum.	e *Keuper, marnes irisées.*

2. LIAS.—LIMESTONE AND LIAS CLAY.

a White lias and micaceous sandstone. *b* Blue lias with marlstone. *c* Lias clay and shale.	*Calcaires à gryphites.*

3. OOLITE LIMESTONE AND BEDS OF CLAY AND SANDSTONE.

a Inferior and Bath oolites with sandstone. *b* Oxford or Clunch clay. *c* Middle oolites. *d* Bituminous or Kimmeridge clay. *d* Upper or Portland oolite.	*Calcaires volitiques,* and sometimes *calcaires de Jura,* and also *calcaire Alpin.*

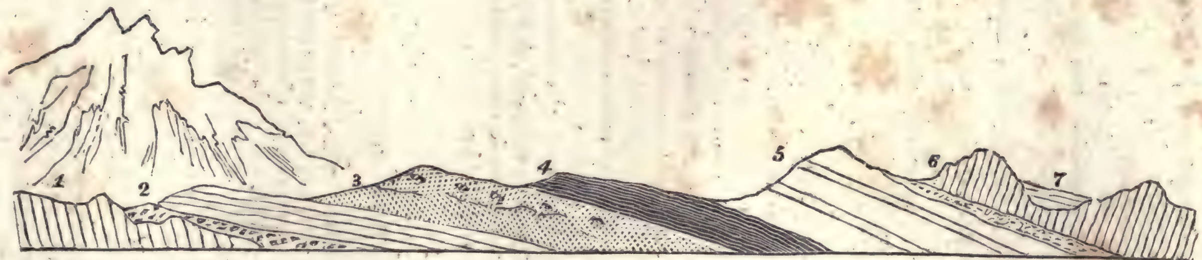
4. WEALDEN OR SUSSEX BEDS.

a White cretaceous limestone. *b* Purbeck strata and limestone. *c* Sandstone and calcareous grit. *d* Weald clay with sandstone.	All the beds of the wealden may be regarded as constituting a local formation of limited extent, but extremely interesting on account of its fossil organic remains.

5. GREEN SAND AND CHALK.

a Lower green sand and iron sand. *b* Blue clay, called Galt. *c* Upper green sand.	*Grès vert et grès ferrugineux.*
d Chalk marl.	*Craie tufeau.*
e Chalk without flints. *f* Upper or Flinty chalk.	*Craie inférieure, et* *Craie supérieure.*

* Foreign geologists are not entirely agreed respecting the place of the *grès des vosges.* The lower beds are generally considered to be the *röth-todte liegende.*



1. Upper transition rocks and coal measures.
2. Lower new red sandstone and magnesian limestone, resting unconformably on transition rocks or coal strata; No. 1.
3. Middle and upper red sandstone and marl, with rock salt and gypsum.
4. Lias clay and lias limestone.
5. Oolite formation, and beds of clay.
   N. B. Where the wealden beds occur, they are placed between the oolite and green sand.
6. Green sand and chalk.
7. Tertiary strata, filling a depression in chalk.

The foregoing cut may assist the geological student to form a distinct notion of the succession and position of the secondary strata, as they rise to the surface, in travelling to the northwest, from the chalk of Surrey to the new red sandstone of Gloucestershire and Worcestershire; but the whole of the series scarcely ever occur together. Thus the magnesian limestone, No. 2, and the upper oolite of No. 5, are wanting in this part of England. In part of Dorsetshire, the chalk and green sand, No. 6, rest upon lias, No. 4, and none of the intervening beds, No. 5, appear. It is sufficient, however, to bear in mind, that whenever the different formations from 2 to 6 occur, they are found subjacent to each other, in the order here represented. Each of these groups or formations has been divided and subdivided into different beds; the most important of these will be afterwards noticed.

New Red Sandstone is so called to distinguish it from a red sandstone found among transition rocks. (See Chap. VII.) The new red sandstone is a very extensive and complex formation: its prevailing mineral character is siliceous; but it sometimes comprises calcareous beds of considerable magnitude and extent. The new red sandstone may be divided into three series, or the upper, the middle, and the lower beds: where intervening beds of limestone occur, they serve to mark the divisions in the series with sufficient distinctness, but where they are wanting, these divisions cannot always be observed. A limestone containing magnesia, separates the lower from the middle series, in the northern counties of England, but is wanting in some of the midland and western counties. In France a calcareous bed, called muschel kalk, separates the middle series from the upper; but this has not been discovered in England.

The red sandstone in England covers the lower rocks unconformably, which proves that the lower rocks were tilted up, before the strata of red sandstone here were deposited: this upheaving of the lower beds must have been attended with great convulsions, which probably supplied the sand and fragments, of which many of the beds of red sandstone are composed. Indeed, it is highly probable, that this sandstone, and the conglomerate beds in different parts of it, were formed by the violent disintegration of the older rocks, and of trap rocks, that were protruded at the era of some great convulsion, which broke down a large portion of the ancient crust of the globe, and spread the debris far and wide over the bed of the existing ocean. Fragments of the older rocks occur in the different beds of this sandstone, and some of the beds are almost entirely formed of such fragments. This mode of formation would sufficiently account for the great diversity, both in the nature and thickness of the beds, in different districts. I am inclined to believe, that the disintegrating causes which broke down part of the ancient rocks, and spread their ru-

ins over a great extent of surface, acted at successive periods of comparatively short duration, succeeded by long intervals of repose, during which the calcareous strata were deposited.

Lower New Red Sandstone was not known as a member of the red sandstone formation in England, before Professor Sedgwick ascertained, that it formed beds of considerable magnitude below the magnesian limestone in Durham and Yorkshire. It does not, however, extend, as he supposed, to the southern termination of the magnesian limestone in Nottinghamshire; for there I have found the lowest beds of magnesian limestone resting immediately on the coal measures, and a part of the upper red sandstone covering the limestone. The lowest beds of red sandstone are in some situations conglomerates; in others, coarse siliceous sandstone is often much intermixed with decomposing crystals of felspar. Sometimes it is found finer grained, and mixed with micaceous shale and reddish marl. The beds are generally more or less impregnated with the oxyd of iron, and colored red or yellow. The thickness of the beds differs much in different situations, as might be expected from its lying upon the lower beds unconformably, and therefore resting upon an uneven surface. The lower new red sandstone in the western counties of England, and in various parts of the Continent, contains fragments of different rocks cemented by ferruginous sand or marl, and masses of imperfect porphyry, and abundance of felspar, both in a decomposed state and in perfect crystals.

The magnesian limestone, over the lower red sandstone, should here be described in the ascending series; but the description would disconnect the account of the upper and lower red sandstone, which are strictly but one formation. I shall, therefore, defer the description of the magnesian limestone, until that of the red sandstone is gone through. In fact, the magnesian limestone does not always occur in the red sandstone.

Upper Red Sandstone and Red Marl above magnesian limestone. In England, where the limestone called Muschel Kalk does not separate the upper red sandstone (grès bigarré) from the red marl above, (Keuper,) they may be regarded as upper and lower beds of the same formation, passing into each other without any well defined line of separation. The upper red sandstone (grès bigarré) varies very much in character and appearance in different situations; it may, however, be generally described, as a siliceous or quartzose sandstone; in some situations, it is finely grained and hard, and furnishes durable building stone. In other situations, it is coarsely granular, soft and perishable, and sometimes graduates into red marl. In some parts the lower beds are a conglomerate, and sometimes it occurs as a soft sandstone, enclosing rounded pebbles of quartz and Lydian stone, granite and porphyry, as in the rock on which Nottingham and the Castle

stand. In the lower part of this division, as well as in that beneath the magnesian limestone, the beds are sometimes porphyritic, and contain imperfect crystals of felspar; sometimes they pass into amygdaloid and trap. The fine siliceous sandstones, when closely examined, are often found to contain fragments of the neighboring rocks: thus the sandstone in the vicinity of Charnwood Forest, as before stated, contains fragments of slate and chlorite slate; and the conglomerate beds on the northern side of that range of hills, are principally composed of fragments of granitic and slate rocks. The color of this sandstone is also as various as its qualities, being red, grey, yellowish brown, or an intermixture of the latter colors with spots and stripes of red. In England this sandstone has frequently been confounded with the red sandstone and conglomerate, that occur under the upper transition limestone, called by English geologists the old red sandstone. But the old red sandstone of foreign geologists, or *roth-todte liegende*,* the *grès ancien* of Daubuisson, covers the coal formation, and therefore corresponds with the lowest beds of the English new red sandstone, before noticed.

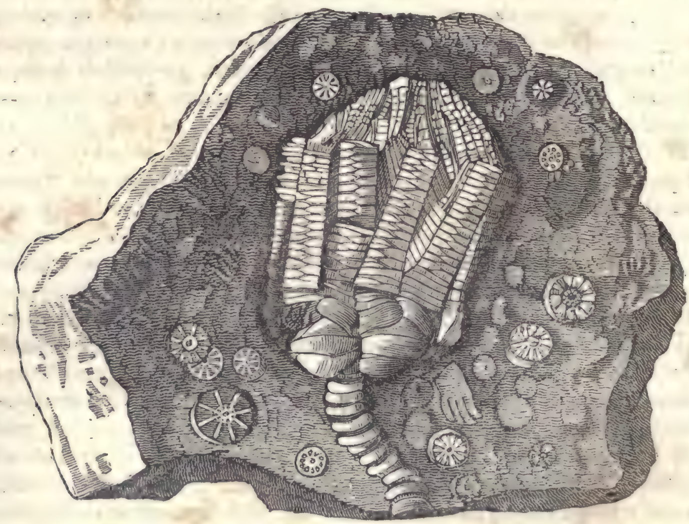
Where the *red marl and sandstone* formation is fully developed, it may be arranged, as before stated, under three divisions: the *lower*, which corresponds with the *roth-todte liegende*, consisting of fragments of different rocks cemented by sand or marl, and of beds of coarse sandstone and of imperfect porphyry; this occurs below magnesian limestone: the *middle beds*, consisting chiefly of sandstone, called by the French *grès rouge*; and the *upper*, consisting of variegated sandstone and marl, in which beds of rock salt and gypsum occur: this corresponds with the *grès bigarré* and *marnes irisées* of the French. In England the three divisions of this formation rarely if ever occur together, accompanied with magnesian limestone; but it should appear, from the situation of these different beds on the Continent, that the place of the magnesian limestone is between the lower and the middle division; for the magnesian limestone or *zetchstein*, rests on the conglomerate beds of red sandstone.

In the third number of the *Annales des Mines*, 1827, there is a very full account of the different arenaceous strata that separate the coal strata from lias limestone, along the feet of the Vosges mountains on the eastern side of France, by M. L. Elie de Beaumont. This account throws considerable light on a part of geology, hitherto obscured by the conflicting opinions of former observers, and assimilates the red sandstone of France and Germany, with the different divisions of the same formation in England. The Vosges mountains are composed of granite and transition

---

* The name Roth-todte liegende, or *red dead lyer*, was first applied to what the English call the old red sandstone, below the coal formation, because no coal was found under it.

rocks, and at their feet there are several coal-fields: the coal strata, and also the lower declivities of the granite, are in part covered unconformably by nearly horizontal strata of red sandstone, and this is covered by lias limestone. We have here, on a larger scale, an exact correspondence with the geology of the Charnwood Forest district, where the granite and slate rocks are bordered by coal strata, and are both partly covered by horizontal strata of red marl and sandstone; and this again is covered by lias limestone. The red sandstone of the Vosges is, however, more developed; the lowest part consists of conglomerate and porphyroidal beds: these cover the coal strata; they agree in their mineral characters precisely with the conglomerates in the English red sandstone, particularly those of Devonshire, and are described by M. Beaumont as being the true *roth-todte liegende.* Above this occurs a considerable thickness of strata of red sandstone, which passes by gradation into the conglomerate; this is the proper *grès rouge;* it approaches in its character nearer to the *grès bigarré* than to the lower beds. The variegated sandstone, or *grès bigarré*, covers the *grès des Vosges*; but there appears to have been a considerable degradation of the surface of the *grès des Vosges*, and also a disturbance of the beds by subsidence or faults, before it was covered by the *grès bigarré* or variegated sandstone: nevertheless they are evidently members of the same formation.



In the beds of the *grès bigarré* there are found thin beds and concretions of magnesian limestone; and above this is a more extensive formation of smoke grey limestone called *muschel kalk*,

abounding in organic remains. In this limestone, the beautiful fossil, the lily encrinite, is found. (See the cut.) The muschel kalk occurs also in Germany, but is entirely wanting in England. In its mineral characters it bears a near resemblance to the limestone called lias, but it is separated from the lias of the Vosges by thick beds, corresponding with the English red marl, but called by the French *marnes irisées*, from their spotted and variegated colors. The fossils in the muschel kalk, bear a nearer relation to those in the lias, than to the shells in the magnesian limestone below it; but neither belemnites nor gryphites occur in this limestone in the Vosges. Its chief fossils are the lily encrinite, two species of ammonite, the terebratula subrotunda, and a species of muscle. According to M. E. Beaumont, were it not for the intervention of the muschel kalk, there would be a complete passage of the red sandstone into the red marl, as occurs in England.

Red Marl. Marnes irisées, Keuper.—This covers the red sandstone, in beds of considerable thickness: it forms a stiff loam, generally of a red color, with greenish or yellowish spots or stripes. Sometimes the beds themselves are of a greenish or yellowish color. These beds are in some situations five hundred feet or more in thickness: this has been ascertained by boring to the rock salt in Worcestershire and Cheshire. It is in this red marl, that the rock salt in England has been hitherto found. It also contains blocks of massive gypsum, and layers of fibrous gypsum. Fine sections are made in this marl by the river Trent at Clifton near Nottingham, and seven miles east of that town; and also by the river Soar at Red Hill, near its junction with the Trent. In all these localities, fibrous gypsum of extraordinary beauty abounds.

The beds of red marl and sandstone of this formation, occupy a considerable part of the midland counties in England, extending from the eastern side of Yorkshire into Devonshire, and on the west, with some interruption, from Cumberland to Gloucestershire. The beds or strata never attain any considerable elevation in England; they cover or enclose rocks of other formations: in Leicestershire and Warwickshire they surround rocks of sienite, granite, porphyry slate, greenstone, and quartz. The granite and greenstone of the Malvern Hills, are covered on the southern side by the same red marl and sandstone. In Devonshire, several rocks of greenstone and amygdaloidal trap are also surrounded by it: and at Rouvray in France, on the road to Dijon, I observed a low range of sienitic and granite rocks, rising from a similar red marl, which, like the English red marl, was covered by blue lias with gryphites. It was formerly maintained by Mr. Farey, that the sienitic and granite rocks of Charnwood Forest and Malvern, were merely anomalous masses in the red marl; and though this opinion was deemed extravagant, and afterwards abandoned by

Mr. Farey himself, I am inclined to believe, that there is a greater connection between these different formations, than has hitherto been admitted.

The red marl and sandstone of England, appear to me to have been principally formed by the disintegration of rocks of trap, greenstone, sienite, and granular quartz: the iron in the decomposing trap rocks, has probably given to this formation its red color. I conceive that the argillaceous marls have also been principally formed from the trap rocks, and the siliceous sandstones from the granular quartz rock. That rocks of sienite, trap, and quartz, were once extensively spread over the districts now covered with red marl, might, I think, be sufficiently ascertained, by tracing them through the red marl districts, where they just peep above the surface, or they might be discovered by sinking. The sienitic rocks of Charnwood Forest may be distinctly traced into Warwickshire; from thence to the Malvern Hills the connection may be followed; and from the Malvern Hills to the trap rocks in Gloucestershire, Somersetshire, and Devonshire; but every where accompanied by the red marl, or near to it. The quartz rock at the Lickey, near Broomsgrove, is not, as has hitherto been believed, the only rock of the kind in the midland counties; it may be found near Atherstone, in Warwickshire, and is doubtless associated with the greenstone rocks in that neighborhood, as members of the Charnwood Forest range of hills.*

I was informed by T. Johnston, Esq. of Exeter, that he had frequently examined the red ground in the vicinity of the different trap rocks in Devonshire, and that he invariably found it composed of fragments of these rocks, increasing in size as he approached nearer to them. The sand rock on which Nottingham and Nottingham Castle are built, has evidently been formed of the ruins of more ancient rocks in its vicinity; and the rounded pebbles of quartz and of Lydian stone, granite, porphyry, jasper, and mica slate, indicate that they have come from rocks, formerly connected with the Charnwood Forest range. Still nearer the Charnwood Hills, the finest sandstone contains fragments of slate; and the lower conglomerate is almost entirely composed of the fragments of the Charnwood rocks, as before observed. In the Vosges, the red sandstone every where accompanies the granitic and transition rocks, of which it also contains fragments. It must be recollected that the rocks most disposed to decompose or disintegrate, would be the soonest worn down. With the exception of the

---

* In the village of Hartshill near Atherstone, when the author was at school there, the quartz rock was employed in mending the roads: it is granular without cement, and breaks into sharp edged fragments; it has a light reddish color. Radiated oxyd of manganese, of an excellent quality, has lately been obtained from this rock in considerable quantities; but whether it occurs in a vein, or imbedded, I have not been informed.

Malvern range, we have no rocks of soft granite, or sienite, in England, like those of Auvergne, or of the Forez mountains in France; and the reason why we have not, may be that, from their smaller magnitude, they were probably carried away by those mighty inundations, that have swept over our present islands and continents. The Malvern Hills, the Lickey, the Charnwood Forest Hills, and the trap rocks in Gloucestershire, Somersetshire, and Devonshire, are the remaining nuclei of much larger ranges, as the scattered fragments in the adjacent, as well as in distant districts attest. If the red marl and sandstone in England, and in other countries, were formed of decomposing rocks of trap, granular quartz, porphyry, sienite, and granite, the frequent occurrence of porphyroidal beds in this formation, may admit of a probable explanation.

It is not intended to maintain, that every bed or stratum in this extensive formation is composed principally of the fragments of transition and trap rocks; but it may safely be affirmed, that there are few strata, in which some of these fragments may not be discovered.

The red marl produces some of the most fertile soils in England, which may be partly owing to its being formed of the debris of soft trap rocks. Some basaltic rocks decompose rapidly, and are known to form soil favorable to vegetation; several basaltic rocks in Staffordshire, decompose into a reddish brown clay, moderately tenacious.

Before concluding the account of the red sandstone, it may be proper to repeat, that in a formation of such complexity, it is often difficult to determine to which part of the series any particular bed belongs, unless its situation be indicated by some of the limestone beds, which sometimes occur in different parts of it. Thus, in Devonshire, the porphyritic beds and conglomerates may belong to the lowest, or to the middle series of sandstones: their position, with respect to the rocks on which they rest unconformably, does not assist in the discovery. In Yorkshire, the very lowest series rest on coal measures, as stated by Professor Sedgwick, in his masterly and luminous description of the geological relations of the magnesian limestone, from Northumberland to Nottinghamshire. At Charnwood Forest, the uppermost series rests on ancient granitic and slate rocks, as represented in Plate III, fig. 4, *a a*. In the lowest beds, resting on the slate, I observed indications of their mode of formation, which I intend afterwards to notice. Professor Sedgwick first ascertained the true relations of the lower sandstone; but twenty years before, in the first edition of this work (1813, p. 270,) I gave a brief account of the Pontefract sand rock (the lowest red sandstone,) in a description of a section from the Yorkshire to the Lancashire coast:—"The magnesian limestone is succeeded by yellow siliceous sandstone, on which the

town of Pontefract is built. We may consider this as the boundary of the low calcareous district: proceeding in a direction to Wakefield, we soon come upon the argillaceous coal strata of the middle district."

It deserves particular notice, that the red sandstone generally occupies the depressions in the more ancient strata, or what were once deep valleys, and also fills up hollows on the surface of ancient rocks, as represented in Plate III, fig. 4, *a a*. Now as these depressions and hollows were originally filled up, when the surface was under the ocean, and are now raised some hundred feet above its present level, without any apparent disturbance, this fact proves, that there were two elevating causes acting at different epochs,—the first violent and transitory, which tilted up the lower beds; the second, more extensive, but more gradual in its operation, which upheaved the whole country above the ocean, and formed islands and continents.

Magnesian Limestone.—The geological position of this rock is over the lowest beds of new red sandstone; but where this is wanting, it lies unconformably over the regular coal formation: see Chap. VIII. It is covered by the upper series of new red sandstone and red marl.

The dolomite found in primitive and transition rocks has been before described; it is commonly white, or light grey and granular. That in the secondary strata, has generally a dark brown or a yellowish brown color: it contains a variable proportion of magnesia, sometimes more than fifty per cent.

The presence of magnesian earth, in the proportion of nearly one half, in certain limestones, is a fact that strongly militates against the theory, which ascribes the formation of all limestone rocks to animal secretion; unless it shall be found that magnesian earth is contained in the shells and exuviæ of marine animals. I believe no analyses of shells or coral have yet been made, in order to ascertain the presence of magnesia, as one of their constituent elements. Should magnesia be found in the exuviæ of certain orders of marine animals, and not in others, it would not only favor the opinion, that limestone was of animal origin, but might also explain the cause of the alternation of beds of magnesian limestone with beds of common limestone, in the same mountain. Or should some shells of one species contain magnesia, and others of the same species none, it would prove that, under different circumstances, the same animal might form its shell of different constituent parts.

Professor Sedgwick is inclined to derive the magnesian limestone from the debris of beds of mountain or transition limestone, which contain magnesia; but many beds of the magnesian limestone, above the coal formation, have as much the character of original rocks as the beds of transition limestone, and the difficulty

is not removed by this hypothesis; for it still remains to inquire, from whence did the mountain or transition limestone derive their magnesia? Von Buch ascribes the change of the common limestone into dolomite in the Tyrol, to the action of volcanic rocks and volcanic vapors containing magnesia; but this opinion is not likely to obtain many supporters. Can the magnesia found in some of the chalk rocks in England or France, be derived from volcanic rocks? Were the theory of Von Buch true, we ought to expect all limestone rocks in the immediate vicinity of basalt to be magnesian; but some experiments which I made on the mountain limestone of Derbyshire, in near proximity to the toadstone, proved that it did not contain so much magnesia, as the beds that were much farther removed from the latter rock.

The magnesian limestone is generally distinctly stratified; the strata vary in thickness from a few inches to several feet: in the northern counties of England they are nearly horizontal; they border the great coal formation, and cover it on the eastern side. This formation of limestone extends from the mouth of the Tyne to near Nottingham. The color of the limestone is generally a yellowish or reddish brown, varying in intensity from a fawn color, to that of an overburnt brick. Some of the lowest beds are bluish and slaty, and intermixed with marl, but these beds seldom rise to the surface, and their nature is little known. Some beds of magnesian limestone have a granular sandy structure, others are imperfectly crystalline: they possess a considerable degree of hardness. A cellular variety of this limestone occurs near Sunderland, which has received the name of Honeycomb limestone: it agrees in most of its characters with the rauche wacke of Thuringia, which is part of the zetchstein formation.

Many beds of magnesian limestone yield a fetid smell when rubbed. At Sunderland, the beds of magnesian limestone are more developed than in any other part of England that I am acquainted with. In an account I published of the Geology of Durham, in the Philosophical Magazine for 1815, I estimated the total thickness at one hundred and fifty yards. Below the surface, this limestone has been bored into, to a considerable depth; the limestone was, as before mentioned, of a bluish color. According to Mr. Farey, "under the yellow beds of magnesian limestone, there are several beds of compact blue limestone, abounding with Anomia (Terebratulæ) and other shells; some of these beds differ entirely from the yellow and red beds, and are more useful for agricultural purposes, particularly on the yellow limestone lands."* This is the marl slate of Professor Sedgwick. The lower beds of this formation are, I believe, more fully developed in many parts of the Continent than in this country, which occasions some

* Survey of Derbyshire, p. 175.

uncertainty in classing them. The limestone of Thuringia, it is agreed by the most respectable geologists, is zetchstein, corresponding with our magnesian limestone; the lower part is a slaty marl, sometimes impregnated with bitumen, and sometimes with sand. This bed contains impressions of fish, like the lower beds of the slaty Sunderland magnesian limestone: it contains also a small quantity of copper pyrites, and the ores of lead, cobalt, zinc, bismuth, and arsenic, and is in some places worked by the miners for its mineral treasures. Above this bed there occurs a blackish grey compact limestone, very hard and tenacious, and distinctly stratified; over this is a cellular limestone; and above this, a blackish brown limestone, which yields a fetid smell when struck with a hammer, and is in some places more than one hundred feet in thickness. All these different beds, Humboldt comprises under the name of zetchstein, and agrees with other geologists in referring them to our magnesian limestone. The lowest bed rests on the red sandstone, and sometimes alternates with it; but according to some geologists, the connection between the two formations of red sandstone and zetchstein is such, that the latter may be regarded as a subordinate formation to the former. The upper beds of what has been called zetchstein, alternate in Switzerland with beds of gypsum, which is intermixed with rock salt: some of the beds are argillaceous limestone, containing ammonites and belemnites, and appeared to me to have a greater resemblance to lias, than to magnesian limestone.

In the lower part of the magnesian limestone in the west of England, there is a conglomerate limestone, which contains fragments of transition limestone, varying in size from several inches in diameter, to very minute grains.

The fossils in magnesian limestone are not numerous, at least in the upper beds. Fossil fish have been found in some of the lower beds in the county of Durham. One or two species of univalves, and about nine species of bivalves, occur in this limestone; but these shells are extremely rare, except in one or two situations. Some of the shells, the *productus* and *spirifer*, nearly resemble those in the mountain limestone, to which the magnesian limestone appears to bear a greater analogy, than to any of the secondary strata above it.

Magnesian limestone furnishes the most durable building stone, that is any where found in the upper secondary strata.

I do not agree in opinion with those who regard the magnesian limestone districts as unfertile; and perhaps no parts of England are more salubrious than those which have a subsoil of this limestone.

A few small strings of lead ore have been found in the magnesian limestone rocks near Sunderland. The limestone rocks on the coast of Durham are wearing away by the violence of the ocean: they have evidently extended much farther eastward than they do at present.

The magnesian limestone of the northeastern counties extends without interruption from the mouth of the Wear, near Sunderland, to near Nottingham; but it does not occur in continuous beds south of the river Trent. The magnesian limestone of the southwestern counties, is no where of any great extent: it forms insulated patches, covering here and there transition limestone, and the coal measures unconformably. The different members of the new red sandstone formation, and magnesian limestone, are more fully developed in the counties of Durham and Yorkshire, than in any other part of England. In Cumberland, near Whitehaven, most of the members of this formation are also found, except the upper new red marl. In the Geological Transactions, 1828 and 1832, a full and detailed account is given, by Professor Sedgwick, of the different beds as they occur in the northeastern and northwestern counties, accompanied with illustrative maps and sections. From these accounts, the following tabular arrangement is extracted.

Professor Sedgwick arranges the red sandstone and magnesian limestone of Durham and Yorkshire, where they are most fully developed, in an ascending series, as under:—

1. Lower red sandstone, yellow and red.
2. Marl slate and compact limestone.
2 *a*. Compact and shelly limestone, and variegated marl.
3. Yellow magnesian limestone.
4. Lower red marl and gypsum.
5. Upper thin bedded limestone.
6. Upper red sandstone.
7. Upper red marl and gypsum.*

The new red sandstone near Whitehaven in Cumberland, has been more recently examined by Professor Sedgwick. It consists of

No. 1. Lower red sandstone of great thickness.
2. Magnesian conglomerate beds.
3. Magnesian limestone.
4. Lower red marl and gypsum.
5. Red and variegated sandstone.

In this part of Cumberland, the great beds of the upper red marl and gypsum of the eastern and midland counties are wanting.

REPOSITORIES OF ROCK SALT AND GYPSUM.

It has before been stated, that, beside magnesian limestone, gypsum and rock salt are associated with the new red marl and

* No. 1, is the same as *a* in my tabular arrangement.
2, 2 *a* and 3, are calcareous divisions of the magnesian limestone *b*.
4 and 5, are minor beds that have not been discovered in the midland counties.
6. Upper red sandstone *c*.
7. Upper red marl and gypsum *e*.

sandstone. Neither of these minerals are, however, confined to this formation. Salt springs rise in many of the coal strata, and gypsum and rock salt are found both in the secondary and tertiary strata; but the occurrence of these minerals has been regarded as most characteristic of the new red marl and sandstone: their principal repositories may therefore with propriety be described in the present chapter.

Gypsum occurs in the new red marl and sandstone, both fibrous and massive. The fibrous gypsum forms numerous alternating seams in cliffs of red marl: the seams vary in thickness from one to three inches, and might be mistaken for strata, but they are irregular and of limited extent. In Nottinghamshire, the fibrous gypsum on the banks of the Trent is often beautifully white and translucent, and is accompanied with scales of chlorite, exactly similar to what I have observed in the beds of gypsum in the Valais, in Switzerland. The white fibrous gypsum is employed by the paper makers to whiten writing paper, and add to its weight. Massive gypsum is granular: it occurs in irregular beds and blocks, in the red marl, and is evidently a local formation. Anhydrous gypsum is occasionally met with in Nottinghamshire. Gypsum is associated with rock salt, wherever the latter mineral is found. It is now discovered, that the gypsum in the Alps, when uncovered in its native beds, is always anhydrous. Common gypsum contains 21 per cent. of water. Anhydrous gypsum is entirely free from water, and is much harder and heavier than common gypsum. Should it prove a general fact, that the gypsum associated with rock salt is always originally anhydrous, it might tend to elucidate the formation of both minerals; a subject which will be referred to, after describing some of the principal repositories of rock salt.

Many repositories of rock salt are situated near the feet of mountain ranges, and have probably been originally deposited in salt-water lakes: beds of rock salt are now found at the bottom of some of the salt lakes in Africa. But though many salt formations are in comparatively low situations, there are others that occur at great altitudes, both in the Alps and the Cordilleras. In England, the principal beds of rock salt are situated at a little distance from the western side of the range of hills, which separate the rivers that flow into the eastern and the western seas.

The rock salt of Cheshire, is found in the red marl above the red sandstone, and probably rests upon that rock; but as the lowest bed of salt has not been sunk through, this cannot be yet ascertained. The upper bed of rock salt in that county, is about forty-two yards below the surface: it is twenty-six yards thick, and is separated from the lower bed of salt by a stratum of argillaceous stone ten yards thick. The lower salt has been sunk into forty yards. The upper bed was discovered about a hundred and

forty years since, in searching for coal. Rock salt at Northwich, extends in a direction from N. E. to S. W. one mile and a half; its further extent in this direction has not been ascertained: its breadth is about fourteen hundred yards. In another part of Cheshire, three beds of rock salt have been found. The uppermost is four feet, the second twelve feet, and the lower has been sunk into twenty five yards, but is not cut through. Besides the beds of rock salt, numerous brine springs, containing more than 25 per cent. of salt, rise in that county. The transparent specimens of rock salt are nearly free from foreign impurities, and contain scarcely any water of crystallization.

In sea water, a large portion of muriate and sulphate of magnesia is found, which gives it that bitter nauseous taste, distinct from its saltness. This difference in the composition of sea water and of rock salt, might seem to indicate that rock salt was not, as some suppose, produced by the evaporation of sea water; but if it were formed in detached lakes, it is possible that the waters of these lakes did not contain precisely the same salts in solution as those of the sea. We know that the waters of some of the salt lakes existing at present, differ in their contents from sea water. If, however, the evaporation were very slow, the salt of the ocean would separate from all its impurities by crystallization; these impurities, being more deliquescent, might be washed away.

It may deserve notice, that few, if any remains of marine or other organized bodies are found in the beds accompanying the rock salt of Cheshire. In the Polish salt mines, bivalve shells and the claws of crabs are met with in the upper strata of marl, and vegetable impressions in the bed covering the lower salt, at the depth of two hundred and twenty five yards from the surface. But some of these mines are now believed to occur in tertiary formations.

The salt formation at Droitwich, in Worcestershire, appears to be surrounded by the same kind of red sand rock, and covered with similar beds of gypsum and marl, to that of Cheshire. Here the rock salt, though its existence has been proved by boring to the depth of five hundred and fifty feet, is no where worked. The salt is procured by evaporating the water, which is nearly saturated with it.

Salt springs rise in some of the coal strata, adjacent to the red marl and sandstone: in all probability the brine is infiltered from that formation, into the basset edges of the strata overlying coal. There are salt springs in some of the coal mines in Northumberland, Derbyshire, and Yorkshire; and a spring of brine rises in the river Wear, in the county of Durham.

Brine springs, containing from five to six per cent. of salt, rise in the coal mines near Ashby-de-la-Zouch in Leicestershire, at

the depth of two hundred aud twenty five yards under the surface. A weaker brine also arises in the upper strata: it springs through fissures in the coal, attended with a hissing noise, occasioned by the emission of hydrogen gas.

The coal mines at Ashby Wolds are in the center of England, and are worked several hundred feet below the level of the sea, which is ascertained from the level of the Oxford canal that passes near to the pits. Had this circumstance been known before the attention of geologists was directed to the structure of the earth's surface, it would have been inferred, that brine springs so far below the level of the sea, had their source from the waters of the ocean, percolating through fissures in the earth.

Strata containing copious brine springs connected with the coal measures occur on the Continent of North America, but rock salt has not yet been discovered there. In the valuable coal districts west of the Alleghany mountains in the United States, there are brine springs both in the strata above and below the coal. The strongest and most abundant supply of brine rises from a stratum of fine grained white sandstone, which, though very compact, contains cavities of several inches in depth, through which the water finds a free circulation. In the Muskingum valley in the State of Ohio, wells have been sunk to the brine to the depth of 900 feet, which is far below the level of the Altantic. The strongest brine yields fifty pounds of fine salt, in every fifty gallons of water.—See *Silliman's American Journal of Science*, October, 1835.

There are many salt springs in France, but no mines of rock salt. The salt springs at Salins, in the department of the Jura, rise in the red marl formation, and the gypsum with which they are associated, is exactly similar to the massive gypsum in the English red marl. The strongest of these springs contains 15 per cent. of salt.

In Switzerland the rock salt and gypsum do not occur in the red marl, but between calcareous beds, which are, I believe, analogous to the English lias, and will be again mentioned.

In Spain there are several salt springs and beds of rock salt; the principal formation of rock salt at Cardona in Catalonia, has been described by Count Alexander Laborde, in his magnificent work entitled *Voyages Pittoresques dans l' Espagne.*

"The salt district of Cardona comprehends the hill on which the town is situated, and the environs of more than a league in circumference. The surface is almost every where covered with vegetable soil to the depth of six inches or more, which renders it productive. The place where the rock salt is procured is a valley forming an oval, about one mile and a half in length, and half a mile in breadth from east to west, extending from the Castle of Cardona to the promontory of red salt at the other end.

The last is the most considerable of the salt rocks, and has not yet been worked; it is six hundred and sixty three feet in height and twelve hundred and twenty feet in breadth at its base. This valley is also traversed by a chain of hills of rock salt: besides these, there are other rocks of salt at the feet of the fortress, and upon the declivity of the mountain which stretches to the fountain called Cancunillo. The mountain of red salt is so called because that color predominates; but the colors vary with the altitude of the sun, and the greater or less quantity of rain. At the foot of this mountain a spring of water issues, which comes through a fissure we perceive on the summit. The rivulet runs all along the valley from the east, but passes under ground in part of its course, particularly under the hill where the rock salt is mined; it rises again to the surface at a little distance, and, after running along the plain, discharges itself into the river Cardona. This brook in rainy seasons swells the waters of the river, which then become salt, and destroy the fish; but at three leagues lower, the water has no perceptible taste of salt. All these salt mountains are intersected by crevices and chasms; and have also spacious grottoes, where are found stalactites of salt, shaped like bunches of grapes, and of various colors."—"Nothing can compare with the magnificence of the spectacle which the mountain of Cardona exhibits at sunrise. Besides the beautiful forms which it presents, it appears to rise above the river like a mountain of precious gems, displaying the various colors produced by the refraction of the solar rays through a prism."—*Count Laborde.*

"Hungary and Poland afford the most numerous and extensive repositories of rock salt in Europe. The salt mines of Welielska near Cracovia have been long celebrated and frequently described; they are worked at the depth of 750 feet. The rock salt is covered by alternate beds of marl and conglomerate; blocks of salt occur also in the marl. The beds of rock salt are inclined at an angle of 40 degrees. It is remarkable, that in these mines of rock salt, there are springs of fresh, as well as of salt water. At Paraid in Transylvania, there is a valley the bottom and sides of which are pure rock salt. The mine of Eperies is about 990 feet deep. Water is sometimes enclosed in the blocks of rock salt."—*Brongniart, Mineralogie.*

There is an extensive formation of rock salt, stretching on each side of the Carpathian mountains for six hundred miles, from Welielska in Poland towards the north, to Rimnie in Moldavia on the south. It has indeed been observed, that rock salt and brine springs most generally occur near the feet of extensive mountain ranges, which adds probability to the opinion, that these ranges were once the boundaries of extensive salt lakes.

In the lofty deserts of Caramania in Asia, according to Chardin, rock salt is so abundant, and the atmosphere so dry, that the inhabitants use it as stone, for building their houses. This mineral is also found on the whole elevated table land of Great Tartary, Thibet, and Indostan. Extensive plains in Persia are covered with a saline efflorescence; and according to the account of travellers, the island of Ormus, in the Persian Gulf, is one large mass of rock salt.

In the elevated mountains of Peru, rock salt is said to occur at the height of 9000 feet above the level of the sea.

According to the account of Hornemann, there is a mass of rock salt spread over the mountains that bound the desert of Libya to the north, so vast that no eye can reach its termination in one direction; and its breadth he computed to be several miles. Rock salt has also been found in New South Wales.

It would exceed the limits intended for the present volume, to enumerate the different places in which this valuable mineral occurs. I only propose to note the more remarkable situations, presenting phenomena that may tend to illustrate the mode of its formation. Among these should not be omitted the salt lakes on the borders of Caffraria, east of the Cape of Good Hope, which contain, at their bottom, thick beds of rock salt variously colored.

There is a remarkable formation of salt at Posa near Burgos, in Castille, placed in an immense crater of an extinct volcano, in which are found pumice stone and puzzolana. The volcanic mountain of Cologero, near Sciacca, in Sicily, contains in its beds a considerable intermixture of common salt; and masses of rock salt occur in other parts of the island, imbedded in clay.* In these, and in some other instances, it is probable that subterranean fire may have been an active agent in the formation of rock salt, by evaporating the waters of salt lakes, or of countries recently emerged from the ocean.

The rapid formation of rock salt in Syria, during one of those igneous eruptions which have at times overwhelmed certain portions of the globe, is, perhaps, obscurely alluded to by the sacred writer, who has narrated the early history of the human race, Gen. chap. xix.† The salt lakes existing in that country are well known.

Whether all the repositories of rock salt above enumerated occur in the red marl, cannot in the present state of our information be accurately ascertained. The great formation of rock salt and gypsum near Bex in Switzerland, constitutes two large and extensive beds. The lowest rests upon black limestone, argillaceous

* Travels in Sicily, by Lieut. General Cockburn.

† Jerome, who resided in Syria in the fourth century, informs us, that the rock of salt was existing in his time; and fancifully relates certain peculiarities respecting it, which equal in absurdity the legends of the darkest ages of papal superstition.

limestone, and sandstone; and between the lower gypsum and the upper, there are thick beds of argillaceous limestone, and similar argillaceous limestone forms caps over the upper gypsum. The gypsum in the large beds is anhydrous, and contains particles of rock salt and common gypsum disseminated through it. The prevailing fossils are ammonites and belemnites.*

The mineral characters of the strata at Bex, and the imbedded fossils, incline me rather to refer the argillaceous limestone, over and under the gypsum and salt beds, to the English lias, than to magnesian limestone. Many beds of the lias in England, contain much muriat of soda and sulphat of magnesia.

The saliferous gypsum in the Tarentaise is anhydrous, and contains a considerable quantity of silex; it occurs interstratified with limestone, which bears a nearer resemblance to the magnesian limestone than to lias. The tops of some of the mountains are covered with beds of common gypsum, intermixed with native sulphur. In one of the rocks associated with the gypsum formation, I discovered a fossil Patella. Though a branch of the *Ecole des Mines*, with able instructors from Paris, had been for some years established at Moutiers, close to the salt formations, a very erroneous opinion respecting the gypsum of the Tarentaise was maintained by the professors; namely, that the gypsum merely formed an unconformable covering over the adjacent mountains. I observed it in several parts of the valley of the Doron, near Moutiers, as distinctly interstratified in the calcareous mountains, as the gypsum of Montmartre is interstratified between the tertiary formations near Paris. In one of the beds of gypsum, there was a thin stratum of carbonaceous matter, which soiled the fingers like coal smut; this is the only instance of carbonaceous matter found in gypsum that I am acquainted with.

Transparent colorless rock salt consists of muriate of soda, nearly in the highest state of purity; or, according to Sir H. Davy, of chlorine and sodium. It has so little water of crystallization, that it scarcely decrepitates when thrown on burning coals, in which it differs from salt prepared artificially by evaporation. Specimens of rock salt brought from the Polish mines, are less disposed to deliquesce, than those from Cheshire. The deep red color, very common to rock salt, is derived from the oxide of iron. Rock salt frequently lies imbedded in clay or marl, in detached masses; the clay is often much impregnated with salt, which is extracted from it by solution in water. The almost constant occurrence of sulphate of lime (gypsum) with rock salt, is also a fact of considerable interest. It is curious to observe the two most powerful acids, the sulphuric and muriatic, so nearly associated in the same place. This fact, in a more advanced state

* Travels in the Tarentaise, p. 415.

of science, may elucidate the chemical changes which have effected the formation of these minerals.

The most natural hypothesis respecting the formation of rock salt, at least in some situations, is that before stated, which attributes it to the gradual evaporation of lakes and pools of salt water, which remained when the ocean retired from the present continents. This mineral, by slow evaporation, would be separated from the impure salts that exist in sea water; and as these salts are more deliquescent than rock salt, they might be washed away before the beds of rock salt were covered with earthy strata.

The occurrence of anhydrous gypsum with rock salt, which is also anhydrous, would, however, indicate the action of heat in the formation of these minerals; for it is scarcely possible to conceive any mode of aqueous deposition, that could form anhydrous gypsum: but common gypsum might be fused by heat, and its water of crystallization expelled; it would then be converted into anhydrous gypsum. From the observations of M. Carpentier, at Bex, it appears that the great beds of gypsum associated with rock salt, are always found to be anhydrous when they are laid open to the atmosphere; but they soon absorb water, and are converted into common gypsum. The saliferous gypsum in other parts of the Alps, is also anhydrous; and if it should appear that the beds of gypsum associated with rock salt in other countries are anhydrous, where they have not been exposed to the action of moisture, it would add much probability to the opinion, that the consolidation of rock salt and gypsum had been effected by heat.

OBSERVATIONS AND INQUIRIES RELATING TO THE NEW RED SANDSTONE.

The new red sandstone, considered as one extensive group or formation, presents greater diversity of character than any other secondary formation; it is for the most part evidently composed of the débris or detritus of older and lower rocks, torn off probably by the great convulsions which at different times tilted up the latter, and spread the fragments far and wide over them, in unconformable beds.

This deposition must have taken place under the ocean, during periods of great violence and disturbance, succeeded by periods of repose, when the calcareous beds of stratified limestone were formed. The state of the globe in those periods of convulsion, was doubtless unfavorable to the existence of organic life. A few fossil vegetable remains occur in the new red sandstone of England, such as calamites and equiseta; but I think it highly probable, that some of these remains have been transported from the coal strata, which, like the rocks below them, must have suffered considerable denudation. There are, however, indications, that dry land or marshes existed in some parts, when the red sandstone was deposited, as the foot marks of a species of tortoise have been discovered,

imprinted on the new red sandstone of Dumfriesshire; and the remains of reptiles have been found in the magnesian conglomerates near Bristol, and of animals, supposed to be saurians, in the new red sandstone of Warwickshire. These discoveries are of importance, as they mark a progressive advancement of animal existence; for no species of reptile has hitherto been found in the coal strata, or in the transition rocks below them. Professor Hitchcock, of Massachusetts, in the United States, has recently observed, in what he describes as new red sandstone, numerous impressions of the feet of birds of the order of Grallæ or Waders.*

These discoveries in the new red sandstone make us acquainted with the earliest known indications of the existence of two higher classes of vertebrated animals, reptiles and birds. In the transition rocks, and the coal measures, we only find the remains of the first or lowest class, fish.

From the great diversity of mineral character in the strata of new red sandstone, in different situations, or even at different depths in the same locality, much uncertainty has prevailed in identifying the beds, particularly the lower ones, in different districts; and geologists are scarcely yet agreed, whether the red sandstone and conglomerates that skirt the southern side of the Grampian mountains in Scotland, belong to the new red sandstone, or to the old red sandstone of the transition series. Indeed, the mineral characters alone could not determine the geological position, without an extensive examination of the relations of the sandstone with the strata above it. It is possible, however, that the sandstone and conglomerates that skirt the Grampians, may neither be of the same age as that of the old red sandstone, or that of the new red sandstone of South Britain. If the red sandstone and conglomerates were formed of the detritus of the lower rocks, at the period when the latter were upheaved, this period may have been very different in distant countries. The granite of the Grampian mountains may have been upraised at a period anterior to the elevation of the granitic mountains in England, or those in Dumfriesshire and the south of Scotland. I have shown, in the preceding chapter, that the elevation of the granitic beds in England, was anterior to the upheaving of the granite of Mont Blanc. The violent convulsions by which the primary mountains were upraised, must have occasioned a long-continued and tremendous agitation of the ocean, sufficient to tear off immense portions of rock, and to break them into fragments, and spread them over a vast extent of surface.†

Whoever has examined with attention the new red sandstone in the vicinity of granitic rocks, will have seen, that it is chiefly composed of fragments of those rocks, intermixed with small grains of sand, cemented together in beds more or less adherent. In the section of Charnwood Forest, (Plate II, fig. 4,) a mass of red sandstone *a*, rests upon elevated beds of slate *c c*. I closely examined the beds in contact with the slate, and found they contained numerous small, sharp-edged fragments of slate, intermixed with small fragments of quartz and forest rocks, imbedded in yellow sandstone, which became striped and colored with red in the upper

* Silliman's American Journal of Science, &c., January, 1836.

† What is considered as the old red sandstone near the Grampians, I found to be in some parts intermixed with particles of green earth and basaltic rocks, particularly, close to Stonehaven, where the red conglomerate is intersected by dykes of harder conglomerate, containing rounded masses of beautiful dark felspar porphyry.

beds. No large masses, or rounded boulders of the forest rocks, occur in the sandstone adjoining the forest. They were probably transported to a distance, during the first period of the convulsion, by which the rocks were upraised. The sandstone formed in depressions of the rocks, was evidently deposited when the violent turbulence of the ocean had nearly subsided, and the water contained only earthy particles and small fragments, washed from rocks in the immediate vicinity of the localities, where the strata are at present found. A vast tract of primary country, extending from Charnwood Forest to the Malvern Hills, has been broken down, and the granite buried under its own ruins. Some of the rocks rise near to, or just above the surface, here and there in the adjacent counties, sufficient to afford proof of their former continuity and connection with the central granite of England. Some of the sandstone formed in the depressions of the forest rocks, is quite red; in other parts close adjacent, it is yellow or striped. The strata of sandstone above the slate at Swithland, are about fifty feet in thickness.

If similar beds of the new red sandstone were formed at periods more or less remote from each other, it may sufficiently explain the different opinions that have been formed, respecting its connection with the coal measures. Some geologists on the Continent maintain, that the lower beds of this sandstone are conformable with the coal measures, and form a part of them. In some parts of England, the lowest new red sandstone is found conformable, to a certain extent, with the coal measures beneath; but in other parts, at a little distance, it occurs unconformably. Too much importance has been attached to this circumstance; for wherever the coal strata take nearly an horizontal position, or are but slightly inclined, the strata of red sandstone above may take the same position, and be conformable in such situations, and unconformable where the subjacent strata are more inclined. Some German geologists maintain, that the lower new red sandstone, the *roth-todte liegende*, occurs also below the coal measures of Germany. It is probable that a stratum, like the limestone shale of Derbyshire, which occurs under the coal of that county, may also occur in Germany. This bed is of great thickness, and is chiefly composed of sands and marl, and contains, in some parts, thick strata of siliceous sandstone: it has a dark reddish brown color, and may be mistaken for the new red sandstone, where its geological relations are not easily to be discovered.

I am not aware that any formation analogous to the new red sandstone, is found in the vicinity of Mont Blanc, or in any other part of Savoy that I examined; though the secondary strata above the red sandstone occur abundantly, and have been upraised with the granitic mountains of that country. If, however, as I think may be proved, the granite was not elevated until after the deposition of the secondary strata, which in England rests upon new red sandstone, and if this sandstone itself is formed from the detritus of the lower rocks, it could not have had a place among the secondary rocks when they were upraised. It is probable that the vast beds of molasse or sandstone, and conglomerates in Savoy, were formed in the same manner as the new red sandstone, but at a much later period, or in the tertiary epoch. I merely offer these observations to the attention of geologists. The elevated beds of puddingstone in the Valorsine, composed of imbedded fragments of mica slate, and the lower rocks, may perhaps be thought to represent the conglomerates of the transition epoch.

The opinion of some of the French geologists respecting the new red sandstone, may here be referred to.

Le Grès masse principale de terrain houiller, prende souvent une grande extension, en abandonnant au moins en majeure partie la houille avec l'argile schisteuse qui l'envelloppe.—*Daubuisson, Traité de Géognosie*, tom. 2.

M. A. H. Bonnard, in his *Apperçu Géognostique des Terrains*, p. 144, describes the red sandstone as the upper part of the coal formation.

A. Humboldt, in his *Essai Géognostique sur le Gisement des Roches*, p. 199, mentions a red sandstone passing into porphyry, as the upper part of the coal formation in Germany.

Messrs. Daubuisson and Bonnard appear to have mistaken the lowest part of the red marl and sandstone, for a portion of the regular coal strata. M. Humboldt makes a distinction between the unconformable red sandstone, and the porphyritic red sandstone, which he cites as a part of the regular coal formation.

CHAPTER XIII.

ON THE LIAS AND OOLITIC SERIES.

Geological Position of Lias Clay and Limestone.—Their Mineral Characters.—Alum Slate in Lias.—Remarkable Organic Remains and Characteristic Fossils.—Extent of the Lias Formation in England.—Interesting Junctions of Lias and Red Marl.—Lias of France and the Alps.—Oolite or Roestone, the Jura Limestone of Foreign Geologists.—Mineral Characters, and remarkable Organic Remains.—Lower Oolite.—Oxford or Clunch Clay.—Middle Oolites.—Kimmeridge Clay.—Upper or Portland Oolites.—Stonesfield Slate—its true position discovered—contains Organic Remains of Insects, Flying Reptiles, and small Land Quadrupeds.—Extent of the Oolite Formation in England, and its abrupt Termination.—Sections of the Oolitic Series of Beds in Yorkshire and the West of England, compared with a Section of the Secondary Strata in Germany.

In England, immediately over the red marl or Keuper, there occurs a great bed of dark grey argillaceous limestone, divided into thin strata, and associated with beds of clay, called Lias. It is the best characterized of all the secondary strata, (except chalk,) both by its mineral characters and its fossil remains; and it presents the same characters, through a considerable part of France and Germany.

The geologist who has taken a comprehensive view of different rock formations, and has compared the resemblance as well as the diversity they present, must frequently have observed a tendency in nature, to reproduce similar strata in distant parts of a series of strata, and even in different formations. In the chapter on the Coal Measures, I have given examples of the repeated recurrence of similar strata at different depths, implying a recurrence of the same conditions under which each had been formed. In the lowest part of the magnesian limestone in the northern counties, there are thin strata of marly limestone, called by Professor Sedgwick, Marl slate, which may be regarded as the first approach to a formation resembling lias, in many of its characters. Again, over the middle beds of the red sandstone, there occurs a considerable thickness of calcareous strata, in many respects resembling lias, called the Muschel kalk; it may, perhaps, when viewed on a large scale, be considered as a lower formation of lias, separated from it by the variegated marls of the upper red sandstone. This bed, as before stated, has not been discovered in England. The lias, therefore, cannot be mistaken for any of the lower strata; it serves as a key to the geology of the secondary formations in England, and the first inquiry which the student should make, when he is in doubt respecting the position of any of the secondary beds, should be,—*Does it occur above or below the lias?*

The name *Lias* was probably given to this formation by the provincial pronunciation of the word *layers*, as the strata of lias limestone are generally very regular and flat, and can easily be raised in slabs from the quarry. When the lias beds are fully developed with their associated beds of clay, they form a mass of stratified limestone and clay, several hundred feet in thickness, which rests upon the red marl described in the preceding chapter.

The regular stratified lias limestone occupies the lower part of the bed, and the lias clay the upper. The lowest beds of the limestone have often a yellowish white color, and are called white lias. The blue lias limestone has a dark smoke-grey color, a dull earthy texture, and an imperfectly conchoidal fracture: the purest beds contain from 80 to 90 per cent. of carbonate of lime, combined with bitumen, alumine, and iron. If iron enter largely into the composition of this limestone, it forms a lime, when burned, which has the property of setting under water.

The finer kinds of white lias will receive a polish, and may be used for lithographic drawings. Above the lias limestone and the lias clay, there occur, in some situations, beds of sandy lias, with layers of ironstone in nodules: this part of the lias formation has been called *marl stone* in some of the midland counties.

The lias clay frequently occurs in the form of soft slate or shale, which divides into very thin laminæ. This shale is often much impregnated with bitumen and with iron pyrites, and will continue to burn slowly when laid in heaps with faggots, and once ignited: during this slow combustion, the sulphur in the iron pyrites is decomposed, and combines with the oxygen of the atmosphere, and with a portion of the alumine in the shale, and forms sulphat of alumine or alum. The alum shale of Whitby in Yorkshire is of this kind; it has rather a soapy feel, and a slight silky lustre. When the lias clay or alum shale falls in large masses from the cliffs upon the sea shore, and gets moistened by sea water, it ignites spontaneously, and continues burning a considerable time. The cliffs of lias clay near Lyme, in Devonshire, took fire after heavy rains, and continued burning for several months, about the middle of the last century. At the present time, a hill near Weymouth is ignited by a similar cause; it is composed of bituminous clay with pyrites, but it is an upper bed in the oolite formation, called Kimmeridge clay.

Lias clay is impregnated with a considerable portion of muriat of soda, and sulphat of magnesia and soda. The mineral springs of Cheltenham and Gloucester rise in this clay; but the mineral qualities decrease after the springs have been opened some time, which proves that the saline matter is derived from parts of the bed adjacent to the springs, and is, therefore, soon exhausted.

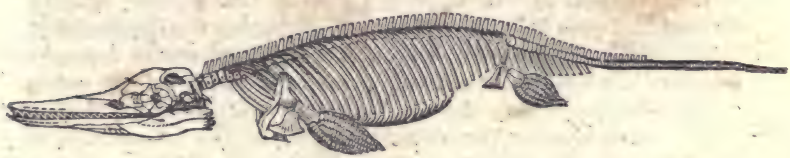
The beds of lias clay and limestone are particularly distinguished by the number and variety of the organic remains which

they contain. Twenty different kinds of ammonites have been discovered in lias, and also nautilites, belemnites, and other chambered shells in great abundance. Univalve unchambered shells are not numerous in this formation, but a great variety of bivalve shells occur in it. The gryphite (*Gryphea incurva*,) a deeply incurved bivalve shell, abounds so much in some of the beds of lias, that in France it has received the name of *Calcaire à gryphites*. Pentacrinites also abound in the upper part of the lias; and in conjunction with gryphites, and the ammonites that have a ridge between two furrows round the back of the shell, are characteristic of the lias formation. The pentacrinite and encrinite were zoophytes with long articulated stems and branches: in the encrinite the stem is round, in the pentacrinite pentagonal. The annexed cut represents part of the branches or arms of the Briarean pentacrinite.

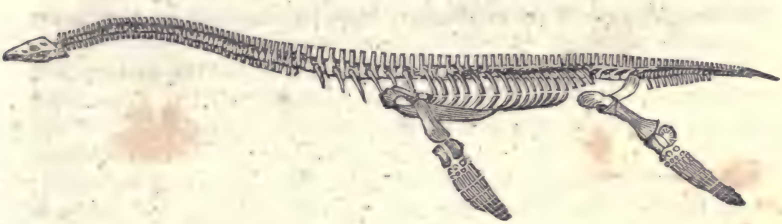
A recent pentacrinite found in Dublin Bay is given, Plate VIII, fig. 17. In this species the arms are less numerous than those of the Briarean pentacrinite: two entire specimens of the latter are represented in Dr. Buckland's B. T., vol. II, plates 51 and 53.

Fossil fish, with the form of the bodies and scales well preserved, are found in flattened nodules of lias limestone. The most remarkable fossil remains in lias, are the skeletons of enormous animals allied to the order of lizards or saurians. The bones and teeth of reptiles have occasionally been found in the new red sandstone; but in the lias and the secondary strata above lias, the bones of saurian animals are so numerous, and of such vast size, that the epoch in which these strata were deposited, has been emphatically called "the age of reptiles." From the structure of these monsters, and the form of their teeth, it is evident that, like the crocodiles and alligators of the present day, they were eminently predacious and carnivorous; they were for a long

period the voracious and dominant aristocracy of the animal kingdom—the lords of the waters and marshes of the ancient world. To the Rev. W. D. Conybeare we are indebted for having determined the forms of two genera of these animals. The ichthyosaurus, or fish lizard, had a head resembling a dolphin more than a lizard, and numerous conical teeth; the orbit of the eye is uncommonly large. Some idea may be formed of the magnitude of these animals, when I mention that the orbit of the eye in a head belonging to Mr. Johnson of Bristol, which I measured, was ten inches long and seven broad: the orbit in another head, belonging to the same gentleman, measured nine inches in breadth.* The vertebræ of the ichthyosaurus nearly resemble



those of a shark, which enabled it to bend its tail with great facility, and assisted the motion of its paddles, in propelling the body with great velocity through water. The skeleton of the ichthyosaurus, as arranged by Mr. Conybeare, is represented in the above cut. Of the ichthyosaurus, several species have been discovered. The plesiosaurus resembles the former genus in many important parts of its osteology; but its vertebræ have a closer approximation to those of the crocodile; they are only slightly concave: its neck was longer than its body, and was composed of thirty vertebræ, which exceeds the number of the cervical vertebræ of the swan. (See the following cut.) Several



species of plesiosauri have been determined; some of them were twenty feet in length. The bones of both animals are found very commonly in the cliffs of lias at Lyme in Dorsetshire, and

* Mr. Johnson of Bristol has, during many years, devoted much time and labor, and has liberally expended considerable sums of money, in collecting organic remains of these saurian animals; and it is to the collection of these remains, in his private museum, that we are principally indebted for the discoveries which have since been made respecting them.

on the southern bank of the Severn. The organic remains in lias are chiefly, but not exclusively, marine. Bones of the turtle and crocodile have been discovered in lias: the fossilized remains of terrestrial plants also occur in it. This proves that dry land must have existed in its vicinity, at the period of its deposition.

A large collection of the fossil skeletons of different species of these saurian animals, from the lias cliffs, at Lyme in Dorsetshire, has been made by Thomas Hawkins, Esq., and described, with plates, in one volume, folio, entitled "*Memoirs of Ichthyosauri and Plesiosauri.*" The specimens themselves have since been purchased and deposited in the British Museum.

The lias formation extends in a waving line through England, from near Whitby in Yorkshire to Lyme in Dorsetshire; at both its extremities it is fully developed, and presents similar features, namely,—dark cliffs of blackish clay or alum shale, with a nearly flat floor of lias limestone, extending into the sea, forming a natural pavement, on which the observer may walk secure, treading at almost every step on the organic remains of the inhabitants of a former world, disseminated through the rock. These animal remains are generally surrounded by stone harder than the other part of the stratum, and project above the surface. At Sandsend, near Whitby, the alum shale has been perforated near the sea, to the depth of one hundred and thirty yards, without penetrating into the subjacent rock; to which, if we add the height of the cliffs above, it will make a total thickness of lias exceeding two hundred and twenty yards: the upper parts are more productive of alum than the lower.* In Dorsetshire, the whole thickness of the lias formation may be seen in succession: a few miles west of Bridport, the uppermost bed rises above the level of the sea; and three miles west of Lime it terminates, and the white lias (the lowest part of its formation) may be observed at low water resting on red marl.

The lias formation is extensively developed on the eastern side of France. In passing by Rouvray to Dijon, in the year 1820, I was exceedingly struck with the complete resemblance of the geology of the country, with that of Leicestershire and Worcestershire. Before arriving at Rouvray, we pass over red marl; after leaving that town, the road traverses a very low range of decomposing sienite and granite rocks, exactly similar to those of Malvern; after which, it passes for several miles over a well characterized lias, filled with gryphites and belemnites: masses of the harder parts, filled with these fossils, are collected for keeping the road in repair.

* Mr. John Phillips, in his recent survey of the Yorkshire coast, estimates the average thickness of the lias, comprising the lower, middle, and upper beds, at 850 feet, or 283 yards.

In England, lias limestone occurs almost always in nearly horizontal strata, and never attains any great elevation. On the west of Gloucester, at Highnam Park, lias limestone forms a nearly flat pavement, resting on red marl, on the summit of a hill about two hundred and fifty feet above the level of the Vale of Severn. From this point to the northwest there is no bed of lias known in England or Wales, except an isolated patch of lias strata in Shropshire, lately discovered by Mr. Murchison; but lias is found in the northwest part of Ireland, and in some of the Hebrides. At Barrow-on-Soar, in Leicestershire, lias rises considerably above the level of the river: it is in the flattened balls that occur in the Barrow limestone, that the finest specimens of fossil fish are found. The most interesting junction of lias and red marl, that I have observed, occurs in the south side of the Severn, at Aust passage, where the red marl may be seen for a considerable distance, supporting the lias, but separated from it by a micaceous bed, filled with broken bones of saurian animals, and other organic remains. Another remarkable junction is mentioned, Chapter II. The lias clay, from its comparative softness, has been more affected by the action of torrents and inundations than the strata above or beneath it: hence it is frequently excavated into valleys. Some of the mountain valleys in the Alps are cut in lias clay. The lias limestone of the Alps and the Jura, loses its flat and parallel stratification, and is bent and contorted in various directions; it also frequently loses its earthy texture, and is hard and semicrystalline, like transition limestone.

The Rev. R. Halifax, of Standish, near Gloucester, obligingly showed me part of the lias and oolite beds in the vicinity of Cheltenham, which he had particularly studied. Between the upper lias clay and the oolite, there is a thick bed of reddish earth with ferruginous nodules inclosing portions of lias; this earth may be seen cropping out, at the foot of Leckhampton Hill. No well-marked natural division exists, which can determine whether this bed should be classed with lias, or the oolites. The fossils in lias clay, and limestone, are nearly black, and are sometimes incrusted with pyrites.

The most valuable mineral substances obtained from lias in England, are water-setting lime and alum shale. The property of setting under water may be communicated to any kind of lime, by an admixture with burned and pulverized ironstone. Many of the bituminous and pyritical shales in the coal strata would yield alum by slow combustion, if they could be obtained with facility. When alum shale is burned, and the soluble part is extracted by water, it is necessary to add potass before the process of evaporation, as crystallized alum is a triple salt, composed of sulphat of alumine and potass.

Oolite.—The numerous beds of yellowish limestone alternating with beds of clay, marl, sand, and sandstone, that compose the oolite formation in England, are of variable thickness; their aggregate average depth, from the top of the upper oolite to the lias, may be estimated at 1200 feet. These beds may be traced with little interruption along a waving line from the Cleveland Hills in Yorkshire into Dorsetshire. In Gloucestershire they compose a lofty range of hills on the south side of the vale of Severn, called the Cotteswold Hills; but no strata of this formation are found in any part of England or Wales northwest of the river Severn. In many parts of France, the oolite strata, accompanied with lias, present all the characters of the same formation in England; but in the Jura mountains, where they are fully developed, the mineral characters often differ considerably; and it is only from the geological position and the imbedded fossils, that they can be identified with the English series.

Oolite or Roestone receives its name from the small globules, like the roe of a fish, that are imbedded in many of the strata: in some instances these globules attain the size of a pea, and this variety has obtained the name of *Pisiform oolite.* In England, nearly all the beds of limestone that are oolitic, in this formation, have a yellowish brown or ochrey color, by which they may at first sight be distinguished from lias. The limestone in which the globules are imbedded has generally an earthy texture, and is dull, and incapable of receiving a polish: some varieties of oolite have been much used for architecture. Somerset House, and many of the public buildings in London, are constructed of this stone; but it is not durable. The occurrence of small oviform globules in limestone is not exclusively confined to the oolite formation: in the magnesian limestone, and even in transition limestone, an oolitic structure may sometimes be observed. It is not yet ascertained, whether these globules are the result of a tendency to crystalline arrangement, or whether they are of animal origin.

The organic remains that occur in the different beds of oolite, are so numerous and various, that it would require an ample volume to describe them fully. It will, however, be necessary to notice those fossil genera that differ remarkably from the genera whose remains are found in the lower strata, and indicate a considerable change in the condition of the globe, or at least in those parts of it where the strata were deposited.

It has been already observed, that the shells in the lower strata were chiefly different species of internal chambered shells, such as nautilites, ammonites, and belemnites, and that univalve unchambered shells were rarely found among them. By far the greater number of genera that have left their remains in these strata, belong to the acephalous Mollusca, or such as had neither

heads nor eyes, and inhabited bivalve shells. Even in the lias, only about five genera of spiral univalve unchambered shells have been well ascertained, and the number of species or of individual shells is small. In the oolite, the genera and species of univalve unchambered shells are more numerous, and the individual shells of several species abound in some of the strata. Now, as these animals had heads and eyes, and moved on their bellies like the land snail, we may infer that they did not live in deep seas, where the sense of vision could not be available; they lived and moved in comparatively shallow water near the shore.

The vertebrated animals, whose remains are found in oolite, are fishes and reptiles of the same genera as those discovered in lias; some undoubtedly belong to the crocodile genus, and had feet, like the living species of crocodiles; hence we may infer, that there were dry land and rivers in the vicinity.

It may well excite surprise, that calcareous strata should so rarely be found, which present distinct indications of having been formed exclusively by coralline polypi; particularly as coral rocks and reefs, of great extent, are so rapidly forming in our present seas. There are, however, among the strata of oolite, some which are almost entirely composed of madreporites, and have received the name of coral ragg. There are other strata which abound in the remains of fossil sponges and alcyonia, and with congeries of minute millepores and madrepores. More than twenty species of trochiform or topshaped spiral shells, and several species of echinites, are found in the oolite strata; but in the lias below, as before stated, only a few genera and species occur, and the individual shells are scarce. The *gryphea incurva*, so common in the lias, is rarely if ever found in the oolite strata; but another species, with a broad expanded shell, called the *gryphea dilatata*, is a fossil frequently found in different beds of the oolite formation. The shells and bones in the oolite limestone, have the yellowish ochrey color of the stone in which they are imbedded; which may serve at once to distinguish them from the lias fossils, that invariably partake of the color of the beds in which they occur. English geologists make three divisions of the oolite formation, which, taken in an ascending series, are denominated the Lower, the Middle, and the Upper oolites. Some confusion has prevailed in the classification of the oolite beds by English geologists, nor was the true position of these beds accurately known: they have recently, however, been attentively examined by Mr. Lonsdale, both in Gloucestershire and in Somersetshire.

The most natural division of the oolites, is formed by three thick argillaceous beds. The lias clay separates the lias from the lower oolites; the Oxford clay separates the lower from the middle division of oolites; and another bed of bituminous clay (call-

ed Kimmeridge clay) separates the middle oolites from the upper or Portland oolite.

The lower oolites, in an ascending series above the lias clay and marl, are—

Cheltenham oolite, commonly called *Inferior oolite*.*
Fuller's earth.
Slaty calcareous limestone, or *Stonesfield slate.*
Great oolite.
Beds of clay, sand, and grit.
Forest marble.
Cornbrash.

Cheltenham oolite, or *inferior oolite.*—In the south of Gloucestershire, this formation, according to Mr. Lonsdale, consists of nearly equal divisions of soft oolite and slightly calcareous sand. The beds of freestone are not lithologically to be distinguished from those of the great oolite; but the beds vary in quality in different situations.

Fuller's earth.—The clay so called is of minor importance in Gloucestershire, but near Bath, the thickness of the beds containing fuller's earth is stated to be one hundred and fifty feet.

Slaty calcareous limestone, called Stonesfield slate from the remarkable organic remains which are found in it at Stonesfield near Blenheim in Oxfordshire. It was formerly supposed to lie above the great oolite; but its true position, as discovered by Mr. Lonsdale, is at the bottom of the great oolite, immediately above the Cheltenham inferior oolite. This stone becomes fissile after exposure to the air: it will be more particularly noticed afterwards.

The great oolite.—This contains the best and largest beds of building stone. In the neighborhood of Bath it is 150 feet in thickness; it consists of softer and harder beds, composed of comminuted shells, intermixed with oolite limestone. The upper and lower beds of the great oolite consist of coarse shelly limestone with oolite, and are called rag stones.

Forest marble consists of coarse laminated shelly oolite, interposed between beds of sandy clay, containing laminæ of grit: it comprises the clay called Bradford clay.

Cornbrash.—This is a thin bed, composed of rubbly hard limestone, generally in detached masses. The external part is brown, but the inner part has often a grey or bluish color. This bed is chiefly remarkable for its numerous fossils.

---

*The name of *Inferior Oolite* given to this limestone must perplex the geological student, as the whole group of beds, including the great oolite, is called the lower oolite. By designating it as Cheltenham oolite this confusion is avoided, and the bed itself is best displayed in the Cotteswold Hills, close to Cheltenham. Whoever visits Cheltenham, may obtain a distinct knowledge of the adjacent geology, by consulting a small pamphlet entitled "Outline of the Geology of the Neighborhood of Cheltenham," by R. J. Murchison, F. R. S. 1834.

The above arrangement of the lower oolites was formed from their occurrence in Somersetshire and the vicinity, where they were first studied, but it by no means represents the general succession of the beds in other countries. In the eastern moorlands of Yorkshire, the oolitic series are well displayed on the coast, and have recently been described by Mr. J. Phillips. Two vast depositions of sandstone, shale, and coal, occur below the cornbrash in the following order, ascending from the lias:—

1. Ferruginous beds above lias, thickness, . . .	60 feet.
2. Lower sandstone, shale, and coal, ...	500
3. Impure limestone, supposed to represent the Bath oolite, ...	60
4. Upper sandstone, shale, and coal, ...	200
5. Cornbrash, ...	5
	825 feet.

This imperfect coal formation appears to be entirely wanting in England, south of the Humber. In Savoy, I examined a coal formation which is placed between two beds of limestone and over lias: this I believe to be analogous, in position, to that in the eastern moorlands of Yorkshire.*

Between the lower and the middle oolites occurs a bed of dark blue clay, called Oxford or clunch clay; the thickness has been estimated at two hundred feet. Some of the beds are bituminous, and bear a near resemblance to lias clay; they abound in Septaria: other beds are much intermixed with calcareous earth. In the lower part of the Oxford clay, irregular beds of limestone occur, which have received the name of Kelloway rock, from being found near Kelloway bridge, in Wiltshire. The bones of one species of icthyosaurus, different from those in the lias, have been found in the Oxford clay.

The oolite above the Oxford clay has sometimes been designated Middle oolite, and Oxford oolite, because the best building stone it affords is in the vicinity of Oxford.

Middle or *Oxford oolite* consists of

Calcareous sandstone and *clay*.
Coral ragg.
Calcareous freestone.

These beds pass into each other, and vary much in thickness in different situations. The coral ragg is so called from its containing in some parts numerous remains of madrepores and coralline animals, *caryophyllia* or cup-shaped madrepores, and *astrea*. The calcareous freestone consists of comminuted fragments of shells in limestone, more or less oolitic; the grains or ova are sometimes

* Travels in the Tarentaise.

as large as peas, hence this variety has received the name of *Pisolite*, or pea stone. The total thickness of the middle oolites is from 150 to 200 feet.

Between the middle and the upper division of oolites, there occurs, in the western counties of England and on the coast of France, near Boulogne, another thick bed of clay, which has received the name of Kimmeridge clay.* It is a greyish clay passing into the state of shale, and is sometimes so bituminous as to be used for fuel: its thickness in some parts is more than three hundred feet. Bones of saurian or lizard-shaped animals have been found in this clay. The ostrea deltoidea is the most characteristic shell in the Kimmeridge clay. It must be observed that the Kimmeridge clay is not found in the northern counties of England.

Upper division of oolite, or *Portland oolite*, consists of
Portland sand, and
Portland stone.

Portland sand.—This bed was first accurately described and designated by Dr. Fitton: it is composed of an intermixture of siliceous and calcareous sand, containing green particles, like those in the green sand hereafter to be described. The Portland sand, near Weymouth, rests upon and graduates into Kimmeridge clay. Its thickness in the Isle of Portland is 80 feet.

Portland stone.—This stone is chiefly obtained for architecture from the Isle of Portland in Dorsetshire; it is there about 70 feet in thickness, but is of different qualities. The best beds may be described as consisting of calcareo-siliceous freestone, more or less oolitic. Portland stone has a yellowish white color, and in the upper part contains large nodules of flint. A similar stone is found also in the Isle of Purbeck; and in a few situations in Wiltshire, Buckinghamshire, and Oxfordshire; and also on the opposite coast of France.

The fossils in the Portland stone, and in the sand beneath it, are all marine, but a remarkable change is observed in the Isle of Portland: immediately over the upper bed of building stone, there is a thin stratum called the dirt bed, containing the silicified remains of terrestrial plants, evidently placed in the situations in which they originally grew. The strata above the bed containing terrestrial plants are of fresh water limestone; these will be noticed in the following chapter.

It would not be compatible with the plan of this work, to enter into a detailed description of all the numerous beds in the extensive formations of oolites: they present general features of resemblance, both in their characters and fossils. There is one bed,

* From Kimmeridge in Dorsetshire, where the bituminous shale is called Kimmeridge coal.

however, so remarkable for its extraordinary organic remains, that it merits the particular attention of the geologist. This is the Stonesfield slate in Oxfordshire, before mentioned, which is now regarded as an undoubted member of the oolite series. Its true geological position has been recently ascertained by Mr. Lonsdale; it occurs immediately below the great oolite, and not above it, as was before supposed.

The Stonesfield slate consists of two beds of yellowish or greyish oolitic limestone, each about two feet thick, and separated by a bed of loose calcareous sandstone about the same thickness. The Stonesfield slate, on exposure to frost, divides into thin plates, which are used for roofing. The stone is obtained by working horizontal galleries in the hill, which galleries communicate with deep perpendicular shafts.

Strata of the same fissile limestone have been traced by Mr. Lonsdale through part of Gloucestershire and Somersetshire; they occur in a similar geological position, beneath the great oolite, but do not contain the remarkable fossils that are found in the Stonesfield slate.

The fossil remains in the Stonesfield slate consist of the impressions of the outer cases or elytra of winged insects, and the bones of small animals of the opossum or didelphis genus, and also the bones of the megalosaurus or gigantic lizard, supposed to be analogous to the monitor. From the size of these bones, it is estimated that the animal to which they belonged, was forty feet in length and twelve feet high. Bones of the legs and thighs of birds were stated to have been discovered in the Stonesfield slate, but a more accurate investigation of these remains proves, that they belonged to a species of flying lizards called pterodactyles. These remarkable animals were of different species, varying from the size of a snipe to that of a cormorant. According to Dr. Buckland, in their external form they somewhat resembled the modern bats, but most of them had the nose elongated like the snout of a crocodile; they were armed with conical teeth, their eyes were of enormous size, enabling them to fly by night. See figures of these animals, Buckland, B. T., vol. 2, pl. 21, 22. The remains of pterodactyles have been found at Lyme Regis, and in limestone of the Jura formation, at Aichstadt and Solenhofen. In the Stonesfield slate are also found teeth, palates, and vertebræ of fishes, and two or three varieties of crabs and lobsters; marine shells, and remains of plants, occur in the same beds. The most extraordinary and anomalous circumstance which the Stonesfield slate offers to our notice is the occurrence of bones of terrestrial mammalia of the same order as the opossum. In no other instance that we are yet acquainted with, have remains of terrestrial mammalia been discovered in the secondary strata. If there were islands inhabited by any of the higher classes of animals when the oolite beds

were forming, their bones may have been carried by rivers into the sea, and deposited with those of marine animals.

But though this hypothesis might satisfactorily explain the occurrence of these remains in the Stonesfield slate, it would still be not less extraordinary, that similar remains should have been nowhere found in any of the upper secondary strata in England, nor in other countries; and that they have never yet been met with, except in strata considerably above the chalk formation. The occurrence of wood, and beds of lignite (or wood coal,) in oolite, confirms the opinion that dry land existed somewhere in the vicinity, at the period when the oolitic beds were formed or deposited; but no indication that the land was inhabited by terrestrial quadrupeds of the class mammalia, has been hitherto discovered, except in the slate of Stonesfield. In Sussex the strata above the oolite contain the bones of the megalosaurus and crocodile, and those of turtles, birds, and fish, similar to the fossils of Stonesfield; but the bones of mammiferous quadrupeds are wanting, and many of the shells are fluviatile. *Where was the island on which the animals lived and flourished, that have left their bones in the strata of Stonesfield?*

The oolite formation extends from the sea coast of Dorsetshire near Bridport, to the northern extremity of the Cleveland Hills in Yorkshire, in one waving range of hills, broken only by the Vale of the Humber. The outcrop of the oolite beds forms the south-western escarpments of this range; and it is truly remarkable, that not a vestige of this formation is found beyond this range, in any of the midland and northwestern counties of England. But some traces of the oolite series have been discovered by Professor Sedgwick, on the northeastern coast of Scotland, and in the isles of Sky and Mull in the western Hebrides.

It may be useful to present the reader with the order of succession and thickness of the beds of oolite and lias, as they occur in two distant parts of England; the Bath district, Somersetshire, by Mr. Lonsdale, and the eastern moorlands of Yorkshire, by Mr. J. Phillips. They are given in a descending series.

BATH DISTRICT.

	Feet.		Feet.
Kimmeridge clay, - -	150	Forest marble:— -	
Upper calcareous grit, -	10	Clay, - - -	15
Coral ragg, - -	40	Sand and grit, - -	40
Clay, - -	40	Clay, - - -	10
Calcareous grit, - -	50	Coarse oolite, - -	25
Oxford clay, - - -	300	Sandy clay and grit, -	10
Kelloway rock, - - -	5	Bradford clay, -	50
Cornbrash, - - -	16	Great oolite, - - -	140

	Feet.		Feet.
Fuller's earth, - - -	150	Blue lias, - - - -	50
Inferior oolite, with sand and grit,	130	White lias, - - -	10
Marlstone, - - -	10	Lower lias marl, resting on red marl and sandstone,	20
Upper lias marl, - - -	200		

EASTERN MOORLANDS.

	Feet.		Feet.
Calcareous grit, - - -	60	Lower sandstone, shale, and coal,	500
Coralline oolite, - - -	60		
Calcareous grit, - - -	80	Ferruginous beds and lower oolite,	60
Oxford clay, - - -	150		
Kelloway rock, - - -	40	Upper lias, - - -	200
Cornbrash, - - -	5	Marlstone, - - - -	150
Upper sandstone, shale, and coal,	200	Lower lias, resting on red marl and sandstone,	500
Impure limestone, - -	30		

In the above sections it will be seen, that though there is a great general resemblance between the principal members in each series, there is a considerable difference in the number and succession of the minor beds; there is also some diversity in the fossils in each series. By a comparison of both sections, it will appear, that the attempt to establish an identity of beds, or even of what are called equivalents, in the minor strata of a great formation in different districts, is a useless labor, and serves only to perplex the student, without leading to any useful conclusions. Nor do I think the long lists of marine shells, in a formation decidedly marine, can be of any great use, unless such shells discover some new forms of organic life distinct from what has been before observed, or unless they enable us to infer some change in the condition of the globe, when the inhabitants of such shells first appeared. The section of Mr. J. Phillips being a coast section, has the disadvantage of not being made in the true line of dip, and that of Mr. Lonsdale was unavoidably taken in different situations where the upper and under strata were not always displayed; hence such sections can only be regarded as valuable approximations to truth in each district. In Yorkshire, the Kimmeridge clay is wanting, and the oolites are covered by the chalk formation, in the lower part of which, called the Speeton clay, some fossils of the Kimmeridge clay have been discovered.

The imperfect coal formations in the Yorkshire oolites, contain impressions and remains of fossil plants of the same families as those in the regular coal formation, but which are stated by M. Adolphe Brongniart to belong to different species.

The attempt has been frequently made, to identify the secondary strata of Germany with those of England. The following abridged view of the secondary strata in the northeast part of Bavaria, in Bohemia, and in Westphalia, by R. J. Murchison, Esq., taken partly from his own observations, and partly from what he believes to be the best authorities, appears to be the most satisfactory and intelligible approximation to the English series of secondary formations that has yet been made. The order of succession in a descending series is here given.

Chalk.	In Hanover, clearly separated from green sand.
Green sand.	Divisible into upper calcareous and lower siliceous sandstone.
Portland oolite.	Oolite and coral ragg, not yet discovered in central Germany.
Solenhofen slate, or supposed *Stonesfield slate.	Between Kehlheim, on the S. E., and Pappenheim, on the N. W., the quarry at Solenhofen is worked for lithographic stone. The fossil contents are pterodactyli, insects, crustaceous animals, and tellenites, with certain plants: these fossils are similar to those found in Stonesfield slate, and occur in a similar geological position.
Middle oolite. Jura kalk.	The beds of this formation differ much in their mineral characters in different parts of Germany, but contain many of the fossils in the English middle oolites.
Inferior oolite.	The inferior oolite of Wirtemberg, Bavaria, Hanover, and Westphalia, analogous to that found on the Yorkshire coast; it rests upon lias.
Lias.	Lias marl, and gryphite limestone, occur in the countries named in the preceding section.
Keuper. Upper red and yellow marl.	A formation of purple, red, and green sandstone, and marl of enormous thickness, reposing on muschel kalk, and surmounted by lias. Mr. Murchison believes that the Keuper is the true representative of the English red and green marls.
Muschel kalk, wanting in England.	More than 600 feet in thickness; contains remains of the ichthyosaurus and plesiosaurus, the crocodile and turtle: the salt mines of Wirtemberg are in this formation.
Bunter sandstone. Lower red sandstone.	Analogous to the English lower red sandstone with magnesian limestone.
Roth-todte liegende. Lowest red sandstone.	The lowest red sandstone of Professor Sedgwick, like the English sandstone: it rests on transition limestone or coal measures.

It is deserving of notice, that many of the beds in the above section not only contain the same fossils as those in the English series, but also preserve the same mineral characters. Where this is the case, we can arrive at satisfactory conclusions; and such beds serve as a key to the discovery of the true nature of the beds above and below them, where the characters may be less clearly defined.

---

* The Stonesfield slate is now discovered to be lower in the oolitic series than the middle oolite, but the remarkable fossils it contains are supposed to be derived from some island or continent to which it was contiguous. The same fossils are not found in this slate, remote from Stonesfield. Any upper stratum of oolite might contain the derivative fossils of Stonesfield, if it had been situated near an island inhabited by similar animals to those whose remains are found in the Stonesfield slate.

CHAPTER XIV.

ON THE FRESH-WATER SECONDARY STRATA, DENOMINATED PURBECK STRATA AND WEALDEN.

Extent of these Strata.—Indications which they afford of repeated Elevations and Depressions of the Earth's Surface.—Purbeck Strata, resting upon the marine Strata of Portland, contain Remains of terrestrial Plants and fresh-water Animals.—Wealds of Sussex, consisting of Hastings Sand and Weald Clay, contain the fossil remains of enormous herbivorous Reptiles.—Dr. Mantell's Description of the supposed Appearance of the Country when these Animals flourished.—The whole surface afterwards submerged under the Ocean, and covered with a Deposition of marine Sand and Chalk.—Observations on the repeated Changes from marine to fresh-water Formations.

The strata which form the subject of the present chapter, are of small geographical extent, being chiefly confined to the counties of Dorset, Hants, Sussex, and Kent: some indications of them have been traced inland, as far as Oxfordshire, and also on the opposite coast of France. But though limited in extent, these strata offer to the contemplation of the geologist proofs of the action of disturbing causes, which may have affected a great portion of the northern hemisphere. A description of the Purbeck and Wealden beds, therefore, becomes an essential part of general geology, and the labors of Dr. Mantell, and Dr. Fitton, have made us acquainted with facts respecting them, that are scarcely exceeded in interest by any discoveries in the lower formations.

Fresh-water limestone, and Purbeck strata.—In the quarries in the Isle of Portland, the succession of the different beds immediately above the Portland stone is distinctly exposed to observation. Over the strata containing remains of marine animals, there is a calcareous bed about two feet in thickness, and upon this is spread a stratum of dark clay, called *dirt*, from two to six inches in thickness, in which are found fossil specimens of cycadeæ, analogous to living species of cycas: they are erect, and apparently in the exact situation in which they once grew. Thus, at the distance of two feet, we find an entire change from marine strata to a stratum once supporting terrestrial plants: and should any doubt arise respecting the original place and position of these plants, there is, over the lower dirt bed, a stratum of fresh-water limestone, and upon this a thicker dirt bed,* containing not only the cycadeæ, but stumps of trees from three to seven feet in height, in an erect position, with their roots extending beneath

---

* The dirt bed, where I examined it, was chiefly composed of carbonaceous matter, and small calcareous stones, slightly rounded, with a very small portion of clay.

them. Stems of trees are found prostrate upon the same stratum; some of them are from twenty to twenty five feet in length, and from one to two feet in diameter. When I visited the quarries in 1833, a very large tree of this kind was lying upon the stratum where it had once grown; the mineral matter that covered it having been removed by the quarry men. These vegetable remains, though imbedded in calcareous earth, are all penetrated with silex. The trees belong to the family of coniferous plants, like the pine. The upper dirt bed, in which the trees appear to have grown, is covered by a slaty fresh-water limestone below the Purbeck stone.

It is very rare that such important changes on the surface of the globe, as from sea to dry land, and from dry land to the depositions of fresh-water lakes or rivers, can be observed so distinctly in the same place, and immediately over each other, as in the Isle of Portland. We can easily imagine how the bed of the sea may be raised, and become dry land, and be covered with terrestrial plants, but it is by no means so easy to imagine, how the same dry land should become the bed of a lake or river, and be buried under a deposition of fresh-water limestone. Such changes, on a very extensive scale, are presented by the Purbeck and Wealden beds.

The following section of a cliff east of Lulworth Cove, Dorset, made by Dr. Buckland, exhibits most clearly, proofs of the alternation from marine strata, to dry land covered with a forest, and of a subsequent submergence of the dry land, under a river or lake, which deposited fresh-water limestone. It will be seen, that both the marine and fresh-water strata were afterwards tilted up together.

A. Portland marine limestone.
B. Ancient forest in the dirt bed.
C. Lower Purbeck beds of fresh-water limestone.

The facts which this section discloses, and the inferences from them, are equally intelligible and interesting.

Purbeck strata.—These consist of slaty limestone, of a brownish color, and more or less argillaceous, alternating with slaty

marl, and in some parts containing beds of compact limestone. The total thickness of the different beds, where they are most developed, in Dorsetshire, is stated by Dr. Fitton to be 274 feet. In the Isle of Portland, the slaty limestone covers the fresh-water limestone, in which are found the silicified trees before mentioned. The whole of the Purbeck beds are considered to be of fresh-water formation. The principal shells are bivalves, called the cyclas, of which a great part of the stone is often composed, and univalve shells, nearly resembling the garden snail, but more elongated, called paludinæ; the latter are most abundant in the upper beds. Remains of crocodiles have also been found in the Purbeck beds. A bed, called Cinder by the quarry men, about twelve feet in thickness, filled with oyster shells, is found in some of the quarries, but this is not supposed to invalidate the general fresh-water character of the formation, as oysters are known to live in the mouths of rivers, as well as in the sea. Whether the Purbeck beds near the coast of Dorsetshire, were once continuous with insulated patches of the same beds in the adjacent counties, and on the opposite coast of France, cannot be certainly ascertained, but it is highly probable, that the isolated portions were once connected, as we have proofs of repeated convulsions, and disruptions of the strata, in the southern counties of England. The Purbeck beds may be regarded as the lower part of the great fresh-water formation, called the Wealden.

The *Wealden* beds cover a considerable part of the wealds of Sussex and Kent; their aggregate thickness is supposed to be about seven or eight hundred feet. These beds consist of clay, common sandstone, calciferous sandstone, conglomerate sandstone, limestone, and ironstone. The order of succession is variable in different parts of the weald, as might be expected in so extensive a sedimentary deposition. The limestone called Petworth marble, occurs in subordinate beds in the clay; it closely resembles some of the Purbeck beds. The Wealden beds, in Sussex and Kent, are every where surrounded by chalk and green sand, except on the east, where they are cut off by the sea. The chalk formation with the green sand is evidently marine, and the fresh-water beds of the Wealden, dip under the chalk and green sand. Here we have, upon a very extensive scale, the evidence of a sudden change from fresh-water to marine beds. The limestone, sandstone, clay, and conglomerate, contain almost exclusively the remains of fresh-water animals, and terrestrial plants, and that over a surface exposed to observation nearly sixty miles in length, and from fifteen to twenty miles in breadth. The marine beds on which the Wealden rest, must, at a remote period, have been raised a considerable height above the ocean, and become dry land, having extensive rivers, lakes, or estuaries filled with fresh water, in which the wealden beds were deposited.

Again, at a subsequent period, the whole must have sunk deep beneath the surface of the sea, and been covered by a deposition of chalk and other marine strata, a thousand feet or more in thickness. At a more recent epoch, the chalk, with the subjacent beds of Wealden, were raised to their present elevation above the neighboring sea. However the present quiescent state of the earth may seem opposed to the admission of such great geological changes, we are irresistibly compelled to resort to these changes, for a satisfactory solution of existing phenomena.

The relative position of the Wealden beds will be understood from the annexed map.

The chalk hills of the North and South Downs will be seen surrounding the Weald country. Below the chalk is the green sand, marked with waving lines, containing, like the chalk, marine fossils exclusively. The fresh-water formations of Weald clay and Hastings sand and sandstone, rise from under the lower green sand. The Weald clay and Hastings sand, have generally been represented as distinct formations, but in reality the whole of the Wealden is composed of beds of clay, limestone, and sandstone, though in the outer part, (marked with dots,) the clay predominates. The sand and sandstone predominate in the central parts, marked by diagonal lines, extending east and west from beyond Horsham to Hastings. In this direction, the sandstone forms a range of hills of considerable elevation. Crowborough beacon, the loftiest part of the range, attains the height of more than 800 feet.

It is true that we do not obtain a section of the Wealden and Purbeck beds in Sussex or Kent, but in some parts of Dorsetshire, near the coast, these beds can be observed, and they are seen to cover the upper or Portland oolites. Some portion of the same beds have been observed in the Isle of Wight; but the

Hastings sand and Weald clay, have not been found in the midland counties of England. The ferruginous character of some of the beds, occasioned them to be, for a long time, mistaken for the iron sand belonging to the green sand formation, hereafter to be described. The names of Hastings or iron sand, Weald clay, and Petworth limestone, have been given to different parts of this accumulation of sand, sandstone, and argillaceous limestone, to which the name of the Wealden or Sussex beds may be collectively applied.

The clay called the Weald clay, may be regarded as the principal member of this formation, to which the sandstone, calciferous grit, and limestone, are subordinate; for though the sand and sandstone form lofty cliffs on the coast, they alternate with marl and clay, and rest on beds of clay.* We shall therefore describe the Weald clay in conjunction with the beds of limestone and sandstone. The clay is a bluish or brownish tenacious clay, sometimes indurated and slaty. Thin beds of limestone, separated by seams of clay, occur in different parts of the Weald clay: they have been known as furnishing a stone for architectural purposes, called Sussex marble, and Petworth marble. Some of the more compact varieties are sufficiently hard to receive a good polish. These beds abound with shells of the paludina, and crusts of the Cypris faba,† and other fresh-water shells.

Masses of calciferous sandstone, nearly resembling the well known sandstone of Fontainbleau, occur in various parts of the Wealden, both in what may be called the Weald-clay, and the lower beds of sand and sandstone, called Hastings sand. The Hastings sandstone is composed of yellowish or whitish grains of sand, very loosely adhering, alternating with beds of clay, and with a small sandstone conglomerate, containing rounded fragments of bones, and scales of fishes. Over this bed there occurs, in some parts of the Weald (particularly at Tilgate Forest,) a bed of coarse conglomerate, consisting of quartz pebbles, and rounded pieces of Lydian stone and jasper, and containing bones and teeth of fishes and saurian animals. The upper sands are generally fawn colored, and contain lignite, bituminous matter, and vegetable impressions.

Ironstone occurs in considerable quantities in the Sussex beds. In the sixteenth century, before the coking of coal for smelting

* Below the Castle rock at Hastings, borings were made in 1829; they were chiefly in clay. The clay from the depth of 120 feet, which I examined, was a whitish grey pipe clay. The borings were made to obtain water for the Pelham Baths. Water was found at the depth of 260 feet, of a good quality, and rose nearly to the surface.

† The Cypris faba is a crustaceous animal in a roundish shell or case, not much larger than a grain of millet. The living species are aquatic monoculi, which swim in fresh water, and deposit their eggs on the leaves of aquatic plants, or in the mud. The paludina is a fresh-water univalve shell.

of iron ore was discovered, two thirds of the iron manufactured in England, was obtained from the Sussex beds.* The Wealds of Kent and Sussex, being then covered with forest trees, supplied the fuel for smelting the ore.

To the indefatigable and scientific researches of Dr. Mantell, F. R. S., we are indebted for a knowledge of the true zoological characters of the Wealden beds, which he has described in his "Illustrations of the Geology of Sussex, with Figures of the Fossils of Tilgate Forest." Dr. Mantell has since published an octavo volume, entitled "The Geology of the Southeast of England." It contains his former and recent discoveries, and a more extended survey of the geology of Sussex and Kent.

The fossil remains of the Wealden beds, consist of petrified trunks of large plants, bearing a resemblance to the palms, arborescent ferns, and the gigantic reeds of tropical climates; also of the shells of fresh-water genera, as the fresh-water muscle, the mya, cyrena, paludina, and Helix vivipara. Some remnais of fish, and three distinct species of turtles, have also been discovered; and the bones, teeth, and scales of at least five gigantic species of the lizard family; namely, the crocodile, the plesiosaurus, the megalosaurus, the iguanodon, and the hylæosaurus or forest lizard.

The crocodilian remains are pronounced by Cuvier to be almost identical with those of the fossil crocodile discovered at Caen in Normandy, which belongs to the genus Gavial, the crocodile of the Ganges.

The Plesiosaurus.—This animal has been noticed, Chaps. II, and X.

The Megalosaurus.—The bones of this animal, found at Tilgate, are similar to those discovered by Dr. Buckland in the Stonesfield strata. The megalosaurus is supposed to approach nearer to the form of the monitor,† than to any other species of living lizard, but its size is so enormous, that Cuvier says, if we suppose it to have possessed the proportions of the monitor, it must have exceeded seventy feet in length.

The Iguanodon.—A nondescript herbivorous reptile, which Cuvier pronounces to be the most extraordinary animal yet discovered. Its structure approaches the nearest to that of the Iguana, a large species of lizard in the West Indies; its length was between sixty and seventy feet, which is double that of the largest living crocodile. But the great peculiarity of the iguanodon

---

* For a knowledge of this fact, I am indebted to a gentleman who has in his possession an ancient work on the iron trade of England, previous to the use of coke.

† The monitor, a species of lizard, which is said to give warning of the approach of the crocodile, by a hissing noise.

is the form of its teeth, which bear a striking resemblance to the grinders of herbivorous mammalia, being evidently intended for mastication, in which respect it differs from all living animals of the lizard family. The herbivorous amphibia gnaw off the vegetable productions on which they feed, but do not chew them.—"Since the vegetable remains," says Dr. Mantell, "with which the teeth of the iguanodon are associated, consist principally of those tribes of plants that are furnished with rough thick stems, and which were probably the principal food of the original animal, we may be permitted to remark, that this peculiar structure of the teeth seems to have been required, to enable the animal to accommodate itself to the condition in which it was placed."—The iguanodon appears also to have possessed a horn, equal in size and not very different in form from the horn of the rhinoceros: in this respect, it resembles a living species of iguana, a native of St. Domingo.

d *c* *b*

e *a*

a, *b*, *c*, represent the teeth of the iguanodon of the natural size; *a* is the front view of the perfect tooth of a young animal; *b* is the front view of a full grown tooth, with the points worn down; *c*, the back view of the tooth; *d* represents a highly magnified tooth of the living iguana. The reader may be surprised at the smallness of the teeth of the iguanodon; but the same proportion takes place in the teeth of all reptiles. A living iguana, five feet in length, has teeth not larger than those of a mouse. *e* is a reduced drawing of the horn.

One of the thigh bones of the iguanodon, in Dr. Mantell's museum, is twenty three inches in circumference. The condyle, or joint of another bone which I measured, was thirty four inches in circumference: enormous claws and toe bones have also been

discovered. Dr. Mantell, in his interesting work, the "Fossils of Tilgate Forest," justly observes, "Were this thigh bone clothed with muscles and integuments of suitable proportions, where is the living animal, that could rival this extremity of a lizard of the primitive ages of the world?"

Dr. Mantell concludes his "Illustrations of the Geology of Sussex" with the following interesting observations:

"We cannot leave this subject without offering a few general remarks on the probable condition of the country, through which the waters flowed that deposited the strata of Tilgate Forest, and on the nature of its animal and vegetable productions. Whether it were an island or a continent, may not be determined; but that it was diversified by hill and valley, and enjoyed a climate of a higher temperature than any part of modern Europe, is more than probable. Several kinds of ferns appear to have constituted the immediate vegetable clothing of the soil: the elegant *Hymenopteris psilotoides*, which probably never attained a greater height than three or four feet, and the beautiful *Pecopteris reticulata*, of still lesser growth, being abundant every where. It is easy to conceive what would be the appearance of the valleys and plains covered with these plants, from that presented by modern tracts, where the common ferns so generally prevail. But the loftier vegetables were so entirely distinct from any that are now known to exist in European countries, that we seek in vain for any thing at all analogous without the tropics. The forests of *Clathrariæ* and *Endogenitæ*, (the plants of which, like some of the recent arborescent ferns, probably attain a height of thirty or forty feet,) must have borne a much greater resemblance to those of tropical regions, than to any that now occur in temperate climates. That the soil was of a sandy nature on the hills and less elevated parts of the country, and argillaceous in the plains and marshes, may be inferred from the vegetable remains, and from the nature of the substances in which they are enclosed. Sand and clay every where prevail in the Hastings strata; nor is it unworthy of remark, that the recent vegetables to which the fossil plants bear the greatest analogy, affect soils of this description. If we attempt to portray the animals of this ancient country, our description will possess more of the character of a romance, than of a legitimate deduction from established facts. Turtles, of various kinds, must have been seen on the banks of its rivers or lakes, and groups of enormous crocodiles basking in the fens and shallows."

"The gigantic *Megalosaurus*, and yet more gigantic *Iguanodon*, to whom the groves of palms and arborescent ferns would be mere beds of reeds, must have been of such prodigious magnitude, that the existing animal creation presents us with no fit objects of comparison. Imagine an animal of the lizard tribe,

three or four times as large as the largest crocodile, having jaws, with teeth equal in size to the incisors of the rhinoceros, and crested with horns: such a creature must have been the iguanodon! Nor were the inhabitants of the waters much less wonderful; witness the plesiosaurus, which only required wings to be a flying dragon; the fishes resembling *Siluri*, *Balistæ*, &c."

Another large fossil reptile, scarcely less remarkable than the iguanodon, was discovered by Dr. Mantell, in the strata of Tilgate Forest, in 1832. This animal was less than the iguanodon. Dr. Mantell, from his profound knowledge of comparative anatomy, has been able to ascertain, that it differs in structure from every known species of living or fossil lizard or crocodile, though it agrees with some of them in many important parts of its osteology. It appears to have had a row of scaly fringes on its back, some of which are seventeen inches in length: when erected, the animal must have had a truly terrific appearance. To this animal Dr. Mantell has given the name of *Hylæosaurus*, or forest lizard: it is described and illustrated by a large and excellent plate, in his valuable work on "The Geology of the Southeast of England." Dr. Mantell has recently added to his collection of fossil reptiles, a more perfect specimen of the remains of the iguanodon, from quarries near Maidstone. It is imbedded in one slab of stone, in which the various parts of the osteology of the animal may be seen in juxtaposition, confirming the sagacious inferences from detached specimens, previously stated by Dr. Mantell. Some of the teeth are seen in the same stone; unfortunately no perfect head or jaw of the animal has hitherto been discovered.

According to the tabular arrangement of the fossils in the different beds in Sussex, given by Dr. Mantell, the chalk, chalk marl, green sand, galt, and lower green sand, above the Wealden beds, contain remains of two hundred and ninety four species of marine animals, and thirteen species of plants, chiefly marine.

The Wealden beds contain remains of fifty two species, which, with few exceptions, are either of terrestrial or fresh-water animals, and nine species of terrestrial plants.

Of the numerous species of chambered marine shells, such as nautilites, ammonites, and belemnites, that abound in the secondary strata, below the Wealden, and in the chalk formation above it, not an individual shell has hitherto been found in any part of the Weald formation; a fact decisive of the different character of the latter beds. With respect to the bones of the plesiosaurus and the megalosaurus, found in the Wealden beds, and also in the strata below the Wealden, we know not whether the nature of these animals might not fit them for living both in salt and fresh water; it is also probable, that the few scattered vertebræ found in the Wealden, may have been transported by currents or

inundations from more ancient rocks. In the same manner, the occurrence of a few individual marine shells, in a series of fresh-water beds, may be satisfactorily explained.

It may be proper to call the attention of the reader to what has been before stated, respecting the submersion of the coal strata, and their being covered with marine formations, and again elevated; see Chapter VIII. The circumstances that attended the elevation and depression of the coal strata, appear to have been similar to what took place at a subsequent period in the Sussex beds or Wealden: other instances of similar submergence might be given were it necessary.

A small work, entitled "A Geological Sketch of the Vicinity of Hastings," was published in 1833, by William Henry Fitton, M. D., F. R. S., &c. It gives a brief, but very clear description of the Wealden formation, the extent of which, Dr. Fitton has taken great pains to discover. According to this statement, the Wealden gradually becomes thinner near its limits in Dorsetshire, and the interior of England. It disappears westward, somewhere about Durdle Cove, on the Dorsetshire coast. The existence of the Purbeck beds in the Vale of Wardour, has long been known: in that place Dr. F. has detected also some traces of sands, corresponding to those of Hastings. "Slaty limestone, like that which occurs in the upper part of the Isle of Portland, is found above the equivalent of the Portland stone at Brill and Whitchurch, west of Aylesbury in Buckinghamshire, and on the coast of the Boulonnois, in France. But besides these places, Beauvais, in the interior of France, is the only other locality in which any members of the Wealden have yet been shown, on good evidence, to exist."

The position of the extreme points of this formation from west to east, or from Lulworth Cove to the boundary of the lower Boulonnois, is about two hundred English miles N. W. to S. E., or from Whitchurch to Beauvais, about two hundred and twenty miles. The depth or thickness of the Wealden beds in some parts exceeds one thousand feet.* Dr. Fitton remarks, that this is a wide diffusion of the strata, if they were the product of an estuary, but by no means greater than that of many of the actual deposits, in some of the larger rivers on the present surface of the globe. Dr. Fitton cites the Deltas of the Ganges, the

---

* Dr. Fitton has since published, in the Transactions of the Geological Society of London, "*Observations on some of the Strata between the Chalk and Oxford Oolite, in the Southeast of England.*" This valuable work, the result of a long continued investigation of the strata from Dorsetshire to Norfolk, contains the clearest and best description of part of the secondary geology of England that has been published, and is so ample as to leave little more to be desired. It is illustrated by maps, plates, and sections: the latter are executed with great care. The coast sections not only present distinctly the geology of the country, but give also the outlines of the physical features and distant scenery, in correct perspective.

Mississippi, and the Quorra or Niger in Africa, as presenting an extent of surface nearly equal to that of the Wealden formation. I think it evident, however, that certain parts of the Wealden were at times dry land, or shallow water. The Cypris faba, in the clay beds, probably lived and died where its crustaceous remains are so abundant. Indeed, we do not remove the necessity of admitting a submergence, by supposing the Wealden to have been deposited in a deep estuary; for to form a large river, and such an estuary, filled with fresh water, extensive tracts of dry land, with mountain ranges of great elevation, would be required, and these must have been submerged or removed, before the deposition of the chalk formation, which it cannot be doubted took place in a deep ocean, as that formation is more than one thousand feet in thickness.

If we inquire *Where was the great island or continent, whose drainage formed a lake or estuary as extensive as the Wealden?* the present surface of the globe affords no answer to this inquiry. The south and east sides of the Wealden are nearly bounded by the sea; the northern side is covered by the chalk formation, which extends into Hertfordshire and the adjacent counties, and rests upon the oolite formation. On the west and southwest, in Hampshire and Dorsetshire, the Wealden beds emerge from under the chalk that bounds them in Sussex, but they become thinner, and, with the Purbeck beds beneath them, cover part of the upper oolite, and terminate near to Weymouth. As the oolite beds on which the Wealden and Purbeck beds rest are marine formations, it is evident they must have been raised above the level of the sea, when the Wealden beds (which they environ) were covered with fresh water. It is however a remarkable fact, that not a vestige of the oolite beds, or the fossils they contain, is found in any part of the Wealden. This negative evidence is of importance, as it proves that the vast depositions of sand and clay, which compose the Wealden, were not derived from the detritus of the oolite, and hence we may infer, that no great river cut through the oolite formation, and flowed into the Wealden lake or estuary. The dry land from which the Wealden depositions were derived, must have been more remote. Perhaps, in the conglomerate beds of Tilgate Forest, if critically examined, may be discovered indications of the character of the ancient country, from whence the grit, sand, and fragments have been transported.

Hitherto the extraordinary organic remains in the Wealden have almost exclusively engaged the attention of geologists. Dr. Mantell, however, informs us, that pebbles of quartz, jasper, and Lydian stone occur in the Tilgate conglomerate. These minerals are precisely such as are found in the sandstone round Nottingham, but a closer examination has discovered in the latter rock, some pebbles of gneiss, granite, and porphyry, derived no

doubt from the debris of the central granitic range of Charnwood Forest, and the adjacent counties. Should similar fragments of primary rocks be found in the Wealden grit and conglomerate, we might, with some probability, refer their origin to a western primary country, once contiguous with the granite of Cornwall and the west of France, but now submerged beneath the Atlantic ocean.

Foreigners or others who intend to survey the most interesting parts of the geology of Dorset, Hants, and Sussex, should previously consult Mr. Webster's Account of the Isle of Wight, in vol. 2 of the Transactions of the Geological Society of London, and his Letters to Sir H. Englefield; the Works of Drs. Mantell and Fitton, before referred to; and an article by the latter, in the Annals of Philosophy, November, 1824, in which the fresh-water character of the Purbeck and Wealden beds was first pointed out. Dr. Buckland and Mr. De la Beche have published an instructive Memoir of the Geology of the Weymouth district, with a map and sections, in the Transactions of the Geological Society of London, second series, vol. 4. This ought to be printed in a compendious form, as a complete guide to the geology of the Isle of Portland and the adjacent country. It is to be regretted, that a more definite account of the numerous faults mentioned in the Memoir could not be obtained, as a surface survey will not enable the most experienced geologist to ascertain the thickness and contents of such faults, and the amount of the depression or elevation of the strata which they traverse. The most unequivocal proofs are given in the Memoir, of the repeated elevation and submergence of the country round Weymouth. Such elevations and depressions must have fractured the surface in various places, and it would be most interesting to examine, by actual inspection, the lines along which the disturbing forces have acted, and the effects they have produced on the adjoining strata. I have stated, page 157, that the funds of scientific societies could not be more usefully employed, than by allowing experienced observers to call in the aid of working miners, to sink pits or cut shafts through supposed faults. Much valuable information would thereby be obtained, and we should substitute certain knowledge for uncertain inferences. By an inadvertence of the artist, some of the faults in the sections given with the Memoir of the Geology of the Weymouth district, are represented in a position in which faults do not occur. The rise of the strata, where the fault is inclined, is placed on the upper, instead of the under side of the fault; an error which may induce foreign geologists to suppose that the faults are hypothetical.

CHAPTER XV.

ON CHALK, AND THE SUBJACENT BEDS OF GREEN SAND.

Extent of the Chalk Formation.—Green Sand divided into lower and upper Green Sand by a Bed of Clay called Gault.—Chalk Marl.—Chalk, its Mineral Characters.—Change of Character in the Alps.—Flints in the upper Chalk.—On the Formation of Flints.—Remarkable Organic Remains in Chalk.—Recent Discovery of Beds belonging to the Chalk Formation, in the United States of America.—On the Scaglia of the Alps supposed to represent Chalk.—On the destruction and denudation of Chalk Rocks.

The well known mineral, chalk, with its subjacent beds of green sand, comprises a formation or series of strata of great depth, which are spread over the southeastern and eastern counties of England, and are found covering a large extent of surface in the northern parts of France, preserving nearly the same characters as the English chalk. Similar beds are found in Germany and in the north of Europe. On approaching the mountain ranges of the northern chain of Alps, the mineral characters of chalk undergo a considerable change. Scarcely a trace of chalk is found in any part of Scotland; but it occurs in the north coast of Ireland.

The animal remains in chalk and its subjacent green sand, are exclusively marine, proving that this great calcareous and arenaceous deposition, a thousand feet or more in thickness, was formed under the ocean.

Chalk is regarded as the last, or uppermost, of the secondary strata; and there is a marked difference between the organic remains in chalk, and those in the tertiary strata that in many situations cover it. The geological position of chalk is over the oolite formation; but we have seen, in the last chapter, that in the counties of Sussex and Kent, chalk and green sand rest immediately upon the fresh-water beds of the Wealden; and in the western counties of England, where the oolite is wanting, chalk covers lias and red marl. The thick beds of green sand under chalk, are regarded as constituting, with the chalk, one marine formation: they contain many of the same genera of fossil remains, both in England and on the continent of Europe, and the lower beds of chalk or chalk marl, pass gradually into the green sand, by a close intermixture with it, and have, on account of their greenish or yellowish color, been denominated *Glauconie crayeuse* and *Craie chloritée*, by the French.

Chalk and green sand have been divided as under, in an ascending series:—

Lower green sand, the upper part ferruginous.
Gault, or Folkstone marl.
Upper green sand.
Chalk marl.
Lower chalk.
Upper chalk with flints.

It has been before noticed, that a repetition of the same mineral characters, may frequently be observed in the lower and higher parts of an extensive series of strata. In the sand below the Portland oolite, there is such a considerable intermixture of green particles, that it closely resembles the green sands of the chalk formation. The green sand below chalk, is distinctly divided into upper and lower, separated by a thick bed of clay. Again, in the sand and sandy concretions over the chalk, the same green particles sometimes abound. These repetitions of similar mineral characters, depend on some prevailing general conditions at different periods of deposition, with which we are unacquainted. The green particles in the green sand below chalk have been analyzed by M. Berthier. In every hundred parts, they contain fifty of silica and twenty one of iron: the remainder consists of alumine, potash, and water.

Green sand has received its English name from its intermixture with particles of green earth; it is very variable in its mineral characters, being sometimes found composed of loose siliceous sand; in other situations it forms sandstone, cemented by calcareous earth; it abounds in siliceous concretions, which vary from an opaque bluish white chert or hornstone, to flint and chalcedony. The geodes found in the green sand near Sidmouth, are composed of opaque chert on the outside, and contain within, mammillated concretions of chalcedony, and occasionally perfect minute rock crystals. Some of the sandy concretions near Sidmouth have a beautiful green color, which I found to proceed from green sulphate of iron.*

The total thickness of the green sand where it is fully developed, is more than 400 feet. The lower sand is generally ferruginous, and has been called iron sand, from the large quantity of oxide of iron disseminated through it; but the lowest beds often contain green particles, like those in the upper green sand. The upper and lower green sand are in many situations separated by a "bed of stiff marl, varying from a light grey to a dark blue." According to Dr. Mantell, its greatest thickness in the south of Sussex is about 250 feet. This bed has been called the Folkstone Marl, but is more generally known by the name of Gault, given

* On the east of Sidmouth, immediately above the town, I observed green sand, intermixed with black particles which I ascertained to be the black oxide of manganese, as they gave a violet color to glass when fused.

to it in Cambridgeshire. The marine shells, in which it abounds, are generally distinguished by their brilliant pearly lustre; they consist of ammonites, nautilites, a small species of belemnite, and various other shells. In some parts of England the gault does not exceed twenty feet in thickness, but according to Dr. Fitton, the constancy with which this bed occurs in the green sand, both in England and on the continent of Europe, is truly deserving attention.

The upper green sand, is remarkable for the chalcedonic appearance of the flint or chert which it contains. This sand has been sometimes called fire stone, to distinguish it from the lower green sand. In some parts of the Savoy Alps, the beds analogous to green sand are of enormous thickness, and are nearly black, but contain many of the same fossils as the English green sand. From these beds I obtained hamites, scaphites, and various species of small echinites. See plate 8. The upper green sand, as before observed, becomes intermixed with an argillaceous and calcareous bed called chalk marl, which may be regarded as the lowest bed of the under chalk. It is of a darker color than common chalk, but burns into useful grey lime.

Chalk.—This rock is better known by its mineral characters in England and the northern parts of Europe, than any other of the secondary strata. Its prevailing color is nearly white; it has an earthy texture, and is generally so soft as to yield to the nail. These are, however, not the universal characters of chalk. The lower beds in Yorkshire are red, and the scaglia of the northern Alps, which is a mode of chalk, has also a red color; and in some parts of the Alps this rock is highly indurated, and resembles more, white statuary marble than English chalk. The greatest thickness of the chalk strata in England may be estimated at from 600 to 800 feet. The upper beds contain numerous nodules and short irregular veins of flint; the lower chalk contains fewer flints, and is generally harder than the upper chalk, and is sometimes used for building stone. In France, the beds of chalk seldom attain the thickness which they have in England. The French divide the chalk formation into the lowest or chalk marl, with green particles, *craie chloritée*, or *glauconie crayeuse;* the middle or coarse chalk is of a greyish color, and intermixed with sand; it contains whitish chert *(craie grossière*, or *craie tufeau;)* the upper or white chalk *(craie blanche,)* which contains nodules of common flint.

M. Humboldt, after noticing the great intermixture of the sandy, calcareous, and argillaceous beds, in the formations below chalk, and which is greatly increased in the tertiary strata above chalk, observes, "that nature seems to have relented in her tendency to form complex mixtures, when chalk was deposited." In the upper and lower chalk, we find a vast assemblage of calcareous

strata, composed of carbonate of lime, with very little intermixture of the other earths, and without any alternation with regular argillaceous or siliceous strata. Chalk is not, however, absolutely pure; for, besides the nodules and veins of flint that occur in it, but which bear no sensible proportion to the whole mass, some of the strata contain an intermixture with siliceous sand, and in other strata, calcareous earth is combined with magnesia. In some of the chalk strata in France, the magnesia exceeds ten per cent., and, I believe, many of the English chalk strata contain as great a proportion of magnesian earth.

Chalk, which contains a notable portion of magnesia, may generally be known by an appearance of dendritical spotted delineations on the surface of the natural partings, and by minute black spots, like grains of gunpowder, in the substance of the chalk.

The stratification of chalk is seldom so distinct as in many other calcareous formations: this may be partly owing to the softness of the beds, which appear to have yielded to pressure; and to the same cause we may probably ascribe the fractured state of the nodules of flint in chalk, which often appear whole, when they are imbedded in the rock, but when taken out, are found to be shivered into innumerable angular fragments. The nodules of flint are commonly arranged in pretty regular layers in the chalk; they occur in detached concretions of various shapes and sizes: some of them are believed to be the casts of spongiform zoophytes, and this is rendered more probable, by the frequent occurrence of fossil echini in chalk, in which the internal part is filled with flint, and forms a perfect cast of the animal. In some of the chalk flints near Paris, there are beautiful small crystals of sulphate of strontian.

The constant occurrence of flint in the upper chalk, and the apparent conversion of animal remains into flint, has formerly given rise to much speculation respecting the origin of flint; and it was at one time maintained, that flint and chalk were convertible or capable of undergoing a mutual transmutation: but whatever hidden processes there may be in the great laboratory of the earth, by which all mineral substances, held to be elementary by the chemist, may be resolved into original elements still more simple, and afterwards recompounded into other substances, we have no reason to mount so high in our speculations, respecting the origin of flint.

Flint is siliceous earth nearly pure; and we find the same earth under different forms, combined with almost all calcareous rocks in a greater or lesser proportion.

Primitive limestone is often much intermixed with siliceous earth. Transition limestone occasionally contains rock crystals imbedded in the mass: this is not unfrequently the case in some of the transition limestones of Derbyshire. The magnesian lime-

stones and oolites are also very commonly intermixed with siliceous grains, and often alternate with strata that are more or less siliceous: hence we need not be surprised to find siliceous earth in chalk, either combined with calcareous earth, or separated in distinct concretions. When the cavities of a sponge or of a crustaceous animal admitted the siliceous earth to enter, it appears to have been infiltered from the chalk, in the same manner as the nodules of chalcedony, have been infiltered into the cavities of lava or basalt. Between chalcedony and flint there is a near resemblance, they are only different modes of the same substance, and the flint nodules in the western counties of England are frequently chalcedonic. The hardest rocks and stones are permeable to water; and flint when first got out of the chalk is easily fractured, and the fractured surface is found covered with moisture.

The organic remains in the chalk formation are exclusively marine. They are too numerous to be described in the present work, but it will be proper to notice those that are the most characteristic. These are, first, echinites, particularly the helmet-shaped species called ananchytes, and the heart-shaped species spatangus cor anguinum. The chambered shells called scaphites, hamites, turrilites, and baculites, are regarded as peculiar to the chalk formation: it also contains ammonites, belemnites, and nautilites. Numerous organic remains of zoophytes, in the state of flint, particularly of sponges and alcyonia, occur in chalk, and various species of bivalve shells; but there are comparatively few spiral univalve shells in this formation. It is probable that the deep ocean in which chalk was deposited, was not suited to the inhabitants of such shells, for the animals had heads and eyes, and required shallow water to see their food. Several species of fossil fish from chalk may be seen in the Mantellian museum at Brighton, and some vertebral remains of large saurian animals, but these are rare. Teeth, palates, and scales of fishes, occur in chalk more frequently than vertebræ. The great preservation in which some of the most delicate organic remains are frequently found, renders it probable that chalk was deposited in a deep and tranquil sea. Balls of iron pyrites, with a radiated diverging structure, are frequently found in chalk; and the large spines of echini, of the genus Cidaris, are found converted into pyrites in the chalk pits near Dorking; they resemble small fungi with a stalk and rounded head.

The vegetable remains in chalk are very few, and appear to belong to species of fuci; but according to M. Brongniart, in the Isle of Aix, near Rochelle, there is a considerable bed of lignite in the lower bed of chalk, which, he says, may have been formed of peat, composed of decayed fuci and other marine plants.

Before concluding this brief account of the organic remains in chalk, it will be proper to notice an important discovery that has been lately made by Dr. Morton, in the United States of America. It had been asserted by M. Humboldt, that neither oolite nor chalk have been found in South America, and such was generally believed to be also the case in North America. At the time when M. Humboldt visited South America, it was not known or even suspected, that chalk and oolite might undergo a change of mineral characters, and be converted into crystalline rocks, resembling primary and transition limestone. I believe I first discovered that the calcareous rocks in Savoy, which were described by the French geologists as primitive and transition limestones, were in reality lias, oolite, and chalk; and about the same period Dr. Buckland made a similar discovery of the true character of the calcareous beds in the Alps, which had been mistaken for transition rocks. It is therefore probable, that many of the calcareous beds in America, may represent the chalk and oolite of Europe. Dr. S. G. Morton has ascertained that there are extensive beds of marl in New Jersey and Maryland (and extending into other States) which contain the characteristic fossils of the chalk formation, particularly baculites and scaphites, together with ammonites, belemnites, echinites (the ananchytes,) the mososaurus and plesiosaurus, also bivalve and univalve shells of the same epoch. This formation in some parts is covered by tertiary strata. Dr. Mantell, whose accurate knowledge of the chalk formation in England will not be disputed, has received specimens of these organic remains from America, and refers them decidedly to the chalk formation, though he considers that some of them are analogous to the superior chalk beds at Maestricht, which are wanting in the chalk formations of France and England. See Silliman's Journal, February, 1832.

Between the epoch when chalk was deposited, and the period when it was covered with the tertiary strata, there appears to have been a considerable interval, during which the surface of the extensive mass of chalk was deeply furrowed and excavated, before a new series of strata were deposited upon it, destined to support a new creation of animals of a superior class, altogether different from those which have left their remains in the subjacent strata. In some situations, however, the tertiary strata appear to rest conformably on chalk, and present no indications of any interruption in the regular series of successive deposits. In an interesting paper, by Professor Sedgwick and R. J. Murchison, Esq., on the relations of the secondary and tertiary strata on the southern flanks of the Tyrolese Alps, published in the Philosophical Magazine, for June, 1829, the tertiary strata are described as forming a vast series of beds resting on scaglia or chalk: the lowest of these beds contain, exclusively, the remains

of marine animals, and no interval of repose can be traced, between the epochs of the formation of the secondary and tertiary strata. The scaglia occurs in beds nearly vertical: the upper beds contain nodules and layers of flints: their color is red, and their structure fissile. The lower beds are thicker, and more compact, and pass into a beautiful white saccharoid marble. The scaglia contains in some parts ammonites and belemnites. It cannot, however, be denied, that where the beds are so much broken and contorted as they are on the Tyrolese Alps, and where their mineral characters differ so much from beds of the chalk formation in England and France, it becomes extremely difficult to ascertain the identity of these secondary depositions in distant countries. In the calcareous formations of the Savoy Alps, I not only discovered the characteristic fossils of the Eng ish strata, but observed some of the beds possessing the true mineral characters of the English oolites, and lias; but where these characters are entirely wanting, and where, from the overturning and contortion of the strata, the aid of relative geological position cannot be obtained, the inferences from a few fossil organic remains must be received with a certain degree of caution.

Chalk in England, and the northern parts of Europe, is less hard and compact, than any other of the secondary calcareous formations. The upper chalk, in some counties denominated soft chalk, is scarcely harder than marl. Chalk itself is provincially called marl in the Isle of Wight. Owing to its softness, chalk has suffered more abrasions and denudations than any other limestone rocks. Cavities, called wells, formed in the chalk near Norwich, and filled with sand and gravel, are often of such vast magnitude, as to impede the farther progress of the workmen in the quarries. Dr. Mantell informs me, that in some of the valleys of Sussex, there are immense accumulations of flint nodules, not in the least water worn, but as perfect as if recently removed from the chalk. I think it probable, that these nodules are the remains of chalk beds so soft, that they have been washed away like mud, without bearing with them the harder and heavier masses of flint. I must here refer the reader to my observations in Chap. IX, respecting the original soft condition of strata beneath the sea, that have never been indurated by elevation and drainage. What is there stated respecting the coal strata, is particularly applicable to chalk. If we bear in mind the soft and yielding state in which chalk probably remained, until its elevation above the ocean, we shall have less difficulty in explaining its subsequent removal, in such cases as the denudation of the Wealds of Sussex and Kent. By referring to the small map in the last chapter, it will be seen that the Weald country is surrounded (except on its eastern side) by lofty ranges of chalk hills, under which the beds of the Wealden dip; and it is believed

that the chalk once extended from the north to the south Downs, as it does at present on the western border of the Wealds. Near the middle of the Wealds, there is a range of hills running from east to west, of considerable elevation, composed of the Hastings sandstone described in the preceding chapter. It is with much probability conjectured, that when these hills were upraised, the chalk which covered them was fractured and broken down as it rose above the level of the sea, and became subjected to the tumultuous agitation of the water. Dr. Mantell justly observes, in his *Geology of the Southeast of England*, p. 346, when treating of the Weald denudation, and the removal of the chalk, "It seems probable that elevation and destruction were going on simultaneously. So soon as the first ridge of chalk on the anticlinal line protruded above the surface of the ocean, it would become exposed to the action of the waves, and as elevation proceeded, degradation would proceed also, until the whole of the chalk strata were carried away, and the Wealden beds in their turn, became exposed to the same destructive agency."

The destruction of the chalk, and its removal, would be greatly accelerated, if, as I believe it probable, the upper beds were full of moisture, and as soft as fresh-made mortar. That such must have been the condition of chalk, for some time after its original deposition, appears evident from facts that will be referred to in the following chapter. The anticlinal line, mentioned by Dr. Mantell, refers to the range of hills extending from Hastings to near Horsham. These hills are composed of the lower beds of the Wealden, which dip in opposite directions, on the north and south sides of the range. This indicates the line, along which the elevating force acted more immediately. Other lines of elevation probably exist in the vicinity, particularly one near the borders of the north Downs, where the green sand of Leigh Hill has been elevated to the height of one thousand feet. These elevating forces have also occasioned a lateral pressure on some of the Wealden beds, giving them a waving form, by which the same bed is repeatedly brought to the surface: hence some geologists have mistaken the reappearance of the same strata, for a succession of different strata, rising from under the upper beds.

CHAPTER XVI.

ON THE FORMATION OF SECONDARY LIMESTONE AND SANDSTONE, AND ON THE PROGRESSIVE DEVELOPMENT OF ORGANIC LIFE.

On the Deposition of Chalk.—Whether formed by Animal Secretion, or by Eruptions of Water holding Calcareous Earth in Suspension or Solution.—Mud Volcanoes.—Animal Bodies suddenly encased in Chalk indicate the Time required to form a Stratum of a given Thickness.—Oolite and Encrinal Limestone partly formed by Animal Secretion.—Formation of Sandstone.—Repeated Appearance of Dry Land during the Epoch when the Secondary Strata were deposited.—Progressive Development of Organic Life in the Secondary and Tertiary Epochs.—Remains of Mammalia in Stonesfield Slate.—Disappearance of enormous Reptiles and large chambered Shells from Northern Latitudes.—Probability of the Ichthyosaurus existing as a living Species in the present Seas.

Having travelled with the reader over the secondary strata, from the lowest new red sandstone to the upper chalk, he may not be disinclined to pause awhile, and look back upon the ground which he has already passed, comprising a series of calcareous, sandy, and argillaceous beds, whose aggregate thickness may not be less than ten thousand feet. It is scarcely possible, in observing these beds, and the bones and shells of extraordinary animals which they contain, not to feel some desire to ascertain the causes by which they were thus entombed, and to inquire in what manner, or by what agents, the different beds were deposited or consolidated. Such researches form rational and legitimate subjects for the meditation of the geologist, though he may frequently have to lament the imperfection of his present knowledge, and the mystery in which many of the processes of nature are still involved.

One of the most ancient geological inquiries relates to the formation of limestone rocks and strata. *Whence was the calcareous matter derived?* Some limestone rocks are chiefly composed of shells, or other calcareous remains of marine animals, and in such instances, we can have little hesitation in ascribing their formation to animal secretion, similar to what is taking place in the numerous coral reefs in the Pacific ocean. There are other beds, however, such as chalk, to which a similar formation cannot be ascribed; for though they contain numerous organic fossils, these do not bear the proportion of one to one hundred millions, when compared to the whole mass, and the chalk does not appear to have undergone any chemical change, from heat or other causes, that could have obliterated the traces of organic existence. In no formation are the most delicate organic textures of animals better preserved. In Dr. Mantell's splendid collection

of chalk fossils, there are specimens of fish, in which the body is entire and the stomach is full and uncompressed; and the beautiful forms of many shells covered with spines, prove that they could not have been drifted from a distance, or deposited in an agitated ocean.

Perhaps the recent discovery of numerous microscopic shells in chalk, may ultimately prove, that the portion of matter formed by animal secretion in chalk beds, is much greater than what is above stated. Forty species of minute shells, allied to the nummulite, (see Plate VIII, fig. 13,) have been found by Count Munster in the chalk of Maestricht. Mr. Lonsdale has discovered sixteen species of similar microscopic shells in English chalk, and also numerous valves of a minute shell, closely resembling the fresh-water cypris. So far, however, as we at present know, these microscopic shells may be regarded as constituting a very small part of cretaceous rocks; but we may infer, that water saturated with calcareous earth, was highly favorable to the increase of some testaceous animals.

I have never been able to comprehend why any peculiar difficulties should be supposed to attend the inquiries respecting the origin of calcareous or magnesian earths; or of the carbon and sulphur occurring in rocks, in the state of carbonic or sulphuric acids. It would be equally proper to institute an inquiry into the origin of silex or alumine. I hold the earth itself, and its ancient atmosphere, to have been the great chemical laboratories, in which all the solid and fluid parts of the surface were originally prepared and formed. This opinion I stated at some length in Chapter XVI, of the second edition of this work, in 1815, and also in the third edition, in a chapter on the agency of subterranean fire in the formation of rocks, and on igneous and aqueous eruptions of earthy matter. It has been too much the fashion to consider all the secondary strata as mechanical depositions; but the siliceous strata in the Paris basin, the layers of flint in chalk, and the beds of chert or hornstone in transition limestone, are certainly as much original formations as granite itself.

In referring to the vast magnitude of ancient volcanoes, I have stated, that they had doubtless an important office to perform in nature: and can it be unreasonable to believe, that the earth itself is the great laboratory and storehouse, where the materials that form its surface were prepared, and from whence they were thrown out upon the surface in an igneous, aqueous, or gaseous state, either as melted lava, or in aqueous solution, or in mechanical admixture with water in the form of mud, or in the comminuted state of powder or sand? Inflammable and more volatile substances may have been emitted in a gaseous state, and become concrete on the surface.

These primeval eruptions, judging from the size of the ancient fissures and craters, may have been sufficient to cover a large portion of the globe. Nor can it be deemed improbable, that still larger and more ancient craters have been entirely covered by succeeding eruptions. In proportion as the formation of the surface advanced, these eruptions might decline, and be more and more limited in their operation.

It is not necessary to suppose that these subterranean eruptions consisted only of lava in a state of fusion. The largest active volcanoes at present existing, throw out the different earths intermixed with water in the form of mud. Nor should we limit the eruptions of earthy matter in solution or suspension, to volcanic craters: the vast fissures or rents which intersect the different rocks, may have served for the passage of siliceous solutions to the surface. We know no instances in nature of siliceous earth being held in aqueous solution, except in the waters of hot or boiling springs; and hence it seems reasonable to infer, that many siliceous rocks and veins have been deposited from subterranean waters, at a high temperature.* Calcareous or cretaceous matter is also ejected during aqueous volcanic eruptions. According to Ferrara, streams of liquid chalk, or chalk in the state of mud, were ejected from the mud volcano of Macaluba, in Sicily, in 1777, which, in a short space, formed a bed several feet in thickness. Beds of limestone may have been formed by similar calcareous eruptions, in which the lime might be sometimes in solution, and sometimes mechanically suspended; and the numerous remains of testaceous animals in limestone, appear to indicate, that the calcareous solutions were favorable to the growth of animals, whose coverings contain so much calcareous matter. Nor is it necessary to suppose, that these aqueous eruptions were always sudden, and attended with violent convulsions, for when a passage was once opened, they may have risen slowly, and have been diffused in a tranquil state, and by gradual deposition, or condensation, may have enveloped the most delicate animals or vegetables, without injuring their external form.—Second edition, 1815.

If the geologist can admit such a condition of the ancient world as above described, a condition which, on a smaller scale, might be proved to have existed since the period of authentic history: if he will further admit, that, before the formation of chalk, a great portion of what is now England, and the northern continent of Europe, was covered by a deep ocean, interspersed with islands, and surrounded by ancient continents, and this few modern geol-

* M. Brongniart, to whom I sent the edition of 1815, subsequently admitted a similar formation of the siliceous beds and millstones in the Paris basin, that they were deposited by thermal waters holding silex in solution.

ogists will deny;—then, if we allow submarine aqueous eruptions of calcareous matter, either in solution or mechanical suspension, and eruptions of siliceous solutions from thermal waters, to have been poured over the bottom of this deep ancient ocean, we shall have all the circumstances required, to form thick beds of chalk, interspersed with layers and nodules of flint. In an experiment on clay formed into a stiff paste, by an admixture with a saturated solution of alum, it was found, on breaking the clay when dry, that alum was interspersed through the mass in distinct crystals and concretions. In the same manner, we may suppose that the silex in the siliceous solutions, spread through the calcareous matter, would separate into distinct concretions, filling the cavities and pores of zoophytes—such as sponges and alcyonia, or of shells deposited in the chalk. Every fact connected with the history of chalk, proves that it was formed in a very tranquil sea, and not by the drift or detritus of more ancient rocks. Dr. Mantell, after many years observation on the chalk formation, says, that in the whole of these immense beds that he has examined, the occurrence of a single fragment or pebble of more ancient rocks in chalk is extremely rare; a fact decisive against its being formed by mechanical deposition of drift, or detritus of older limestones. The preservation of the most delicate textures of animals before referred to, proves beyond doubt, that those organic bodies had not been transported from a distance, or subjected to the violent action of inundations or currents.

From the uncompressed state of the bodies of fish found in chalk, and from the flint nodules imbedded in the upper chalk containing animal remains, we may learn that chalk was deposited in a soft state like paste or mud, and remained soft for a considerable time, allowing the silex disseminated in solution through the mass, to be formed into distinct concretions by chemical affinity and attraction. The flints found in the chalk near Paris, in which are extremely delicate crystals of sulphate of strontian, have been deposited from a solution of siliceous earth containing a portion of strontian. The crystals are too delicate to have formed a nucleus for the siliceous earth to surround; they are found adhering to the fractured surface of the flint, and are disseminated over it. The fossil fish in chalk, with their bodies entire and uncompressed, prove that the chalk which surrounded them, was extremely soft and yielding, and this must also have been the case with all argillaceous strata, that contain remains of fish, not flattened by pressure. We further learn, that the animals were encased in mineral matter, before the putrefactive process had effected the decomposition of the fleshy parts. A sudden eruption of thermal water holding calcareous earth in solution or suspension, might instantly deprive the animal of life, and protect the body from decay. The matter, called *creta* by Ferrara, erup-

ted from Macaluba, was certainly a soft limestone, analog chalk; and though the eruption lasted only part of a da formed a stratum many feet in thickness. Had this erup taken place under water, the earthy matter would have be more widely diffused, and the stratum of limestone deposited would have been proportionably thinner. In the case of fossil fish before stated, we are not obliged to suppose the deposition to be so rapid: several days might elapse before the body was entirely buried under calcareous earth. If we say seven days, and estimate the thickness of the fish at three inches, we shall have a chronometer to measure the time required to form a stratum of chalk three inches in depth, viz. one week. This is equal to one foot in a month, or twelve feet in a year; and could we suppose the deposition to proceed without interruption, it would not require more than ninety years to form a mass of chalk beds, one thousand feet in thickness; which is more than that of all the chalk beds in England. It is by no means intended to support the opinion, that the chalk beds were all deposited in so short a period; long intervals of repose might elapse between different eruptions.

My object in directing the attention of geologists to this subject is, to show that strata may be formed more rapidly than they are generally disposed to believe, and that the feeble operations of natural causes in our own times, however similar in kind, bear no proportion, in their intensity, to the mighty agents that have formed the ancient crust of the globe. The deposition of a bed of calcareous earth, a few feet in thickness in some of the Scottish lakes, as described by Mr. Lyell, would appear to have required many centuries for its completion. In some of the beds of oolite, the quantity of animal remains bears a considerable proportion to the whole mass, and the beds of encrinal limestone in some of our mountain limestones, are formed principally of the broken stems and branches of encrinites; but it is not improbable, that the interstices have been filled by calcareous depositions. It is obvious, that limestone strata of considerable thickness, if composed chiefly of organic remains, would require centuries for their completion.

Let us now take a brief survey of the beds of secondary sand and sandstone. The lowest or new red sandstone, appears to have been formed in an epoch of volcanic action over a large portion of the present European continent, which broke up the foundation of primary and transition rocks, and scattered their fragments over the bed of an ancient ocean. See Chap. XII, p. 210. In many parts we observe a tendency to form beds of porphyry, but the process appears to have been often more or less interrupted by disturbing causes; and we observe porphyritic beds, with well defined crystals of felspar, alternating with sandstone

of mechanical formation. We may further observe, that in this epoch of disturbance, there were long intervals of repose, during which the beds of magnesian limestone and muschel-kalk, were deposited in certain situations.

The operations of mechanical causes are obvious in almost all sandstone rocks, and beds of conglomerate, and the experiments of Sir James Hall prove, that beds of loose sand may be agglutinated into sandstone, if permeated by steam from saline water at a high temperature. In some extensive beds of loose sand or conglomerate, there are masses and concretions of siliceous stone. Dr. Fitton, in his *Observations*, p. 332, says, "This fact, though of universal occurrence in the secondary strata, is especially remarkable in the lower green sand, and Hastings sand of Sussex and Kent." The tendency to concretional formations may arise from chemical action and separation, as in the case of concretions of alum and clay before mentioned; or thermal water, containing siliceous solutions, may have penetrated to different parts of the beds of sand, and united the particles into compact masses. Siliceous sand, cemented by calcareous earth into stone, (called calciferous sandstone,) has probably been formed by the penetration of water saturated with calcareous earth. The tendency to concretional separation, may sometimes be observed in recent admixtures of earth. It is owing to this tendency to form separate concretions, that the earth prepared for porcelain at Sevres, near Paris, which is finely ground into a kind of stiff paste, and kept for several years, is repeatedly ground again, to prevent the separation of the felspar and quartz, of which it is chiefly composed. The late Lord Clifford of Chudleigh, in Devonshire, showed me arable fields which had received successive dressings of lime, at stated intervals of some years, and he informed me, it was discovered by digging, that at different depths from the surface, layers or strata of lime were found separated from each other, by layers or strata of soil, each dressing of lime having formed a distinct stratum.

With respect to beds of clay, their formation by sedimentary deposition will not be doubted; but we are not certain that in some instances, the matter may not have been ejected by submarine mud volcanoes, containing the sulphur, iron, and saline matter, in which several of these beds abound.

One of the most interesting circumstances attending the secondary strata is, the convincing evidence they afford, that at different periods of their formation, the earth had extensive tracts of dry land, either islands or continents; for though the prevailing character of the secondary strata is that of marine beds, yet we find among them beds containing exclusively fresh-water shells, and also terrestrial and marsh plants, and in almost all the secondary strata (except chalk,) though the organic remains may be

chiefly marine, we find remains of some fresh-water animals, or terrestrial plants, which were probably brought by rivers from the land, and deposited in the ancient ocean. We have, beside the above evidence, the regular coal strata, 3000 feet or more in thickness, abounding in terrestrial plants. We have also a great thickness of fresh-water strata in some parts of the oolite formation, and the Wealden strata, more than a thousand feet in thickness, appear to have been deposited in a fresh-water estuary or river, which would require a large continent of dry land for its formation. Now, it is remarkable, that, in all the above beds, we do not find a single bone of any large mammiferous land quadruped, nor even a bone of the smallest species, except in the anomalous instance of Stonesfield.

To maintain that such bones not having been discovered, is no evidence that they may not exist, appears to me to be making a retrograde step in science. It is true, that "the bottom of the sea has not been dredged," to discover what species of animals have existed in former ages: the geologist, however, can have no need of such an operation, for the land beneath the former sea has been laid bare, and is now exposed over an extent, equal to that of all the habitable parts of the globe. Every island and continent has formed part of an ancient bed of the ocean, and that not once, but repeatedly; and this extended surface of the ancient bed, is exposed to the examination of thousands of observers, in every degree of latitude, not covered by polar snows. The absence of remains of the higher order of animals in all the secondary strata, and the frequent recurrence of these remains in the more recent or tertiary strata, appear to afford presumptive evidence, amounting almost to certainty, that the higher orders did not exist, at least in the northern hemisphere, till an epoch subsequent to the deposition of all the secondary formations.

The bones of terrestrial mammalia allied to the opossum, found in the secondary strata of Stonesfield, afford, if attentively considered, proofs of the progressive advancement of organic life, in ascending from the most ancient to the most recent formations. Mr. Owen, by an anatomical examination of the animals of this order, has ascertained, that the brain and nervous system are less fully developed than in the other orders of terrestrial mammalia, and approach to the condition of reptiles. See Phil. Trans. of London, 1834. The fact of their bringing forth their young in a very imperfect state, and retaining them in a pouch or marsupium until they are more fully grown, further proves that they hold an intermediate place between oviparous reptiles, and the other orders of mammalia. From the pouch or *marsupium* destined for the reception of their young, this order of animals is called by Cuvier *marsupial*. The ornithorhynchus of New Holland, is said to resemble marsupial animals in some parts of its organiza-

tion, and it is not yet ascertained whether the animal is viviparous or oviparous.—*Regne Animal*, tom. i, p. 235.

When we ascend to the strata deposited at a later period than chalk, we find a remarkable change in the character of the organic remains. The ammonites, and other chambered shells, which are so numerous in the secondary strata, disappear entirely in the tertiary strata, except the fossil nautilus, which is occasionally found in these strata, and the animal now exists as a living species in the Indian ocean. The enormous lizards, and animals allied to the lizard and crocodile, whose bones abound in the secondary strata, from lias to chalk, disappear also in the tertiary strata, with the rare exception of a small species of crocodile;—a fact which indicates, that animals of this order ceased to be inhabitants of northern latitudes, when the tertiary strata were deposited. In the tertiary strata, the place of these enormous reptiles is occupied by the remains of cetaceous mammalia like the whale, and by higher orders of terrestrial mammalia, but belonging to genera or species now extinct; the gigantic mastodon, the mammoth, and megatherium, rivalled in magnitude the enormous reptiles of a more ancient world. Other species of mammalia of lesser size, both herbivorous and carnivorous, but equally perfect in their organization with the land quadrupeds of the present epoch, have left their bones in many of the tertiary beds. Here we may stop; for we approach to a period connected with the present order of things, a period immediately preceding that mysterious operation of divine power and intelligence, the creation of man.

The doctrine of the progressive development of organic life,* here briefly stated, has been recently opposed by highly ingenious arguments, but which, in my opinion, do not the least invalidate the truth of the doctrine,—a doctrine, however, that like almost all general conclusions, requires to be admitted with certain limitations and restrictions. Every instance hitherto adduced, of bones of the higher orders of animals being found in ancient secondary strata, have proved, on accurate examination, to be fallacious. An instance of this kind came under my observation when on a visit to my native town, Nottingham, in 1830. A medical gentleman showed me the portion of the thigh bone of an ox, which he had treasured with great care, as it was obtained from a deep excavation on the side of a hill of sandstone, near Nottingham. As this sandstone belongs to the more ancient of the secondary strata, the red sandstone and marl, (see

* By the "progressive development of organic life," is to be understood, not the transmutation of one species into another species of a higher order, but a successive creation of more perfect animals, as the world became suited for their support and increase.

Chapter XII,) and as the bone was placed deep under the surface, and the workmen declared there was no fissure or opening near to where the bone was found, the specimen was regarded as affording a remarkable exception to a general law in geology. Knowing from the structure of the rock, that it is almost every where intersected by deep vertical fissures, I was persuaded that the true position of the bone had not been correctly stated by the workmen; and, on carefully examining the cave, a deep fissure, extending to the surface, was discovered close to the situation where the bone was found. There can be no doubt, that the bone had fallen into this fissure, and was thus introduced into a lower stratum of sand rock.

When we consider the violent convulsions and overturnings to which the crust of the globe has been subjected, it is truly surprising, that remains of the higher orders of animals should not have been frequently buried in the lower ancient strata, if they had previously existed.

In the long ages of change and disturbance, during which the solid surface of our planet was approaching to its present state, we may reasonably believe that the earth was not fitted to be the residence of man and the higher order of animals. Even those geologists who deny the progressive development of organic life, admit that man is a recent inhabitant of the globe; but if, as they maintain, the essential conditions of the earth have been the same as at present, during an indefinite series of ages; if the same causes have always been in operation, without any increased intensity of action; if the earth, from the remotest imaginable epoch, had islands and continents, rivers and seas, enjoying a similar temperature to the present, though placed in different latitudes: if such, I repeat, were, from the remotest epoch, the condition of the globe, no assignable reason can be imagined, why it might not have been inhabited by man. If the same changes were only taking place that we observe at present, or even supposing them to be more extensive in their operation, yet the human race might still have flourished in

> " Some safe retreat in depth of woods embraced,
> Some happy island in the watery waste."

But the more ancient strata present evidence of overwhelming changes and mighty convulsions, that have elevated mountain ranges, broken the solid crust of the globe, and scattered the fragments in every direction. During these epochs of disturbance, neither the earth nor the atmosphere could be fitted for the residence of man, or the higher order of animals; nor do we find among the secondary strata that have once been dry land, any remains of its former inhabitants, except the bones of enormous reptiles.

Though man, and the higher orders of animals, could not exist during an epoch of universal disturbance, yet we can discover no reason why many genera and species, particularly of marine animals, that have formerly existed, should be now extinct, unless a change has taken place in the temperature of the globe. Indeed, it is found that many genera, which are only discovered in a fossil state in Europe, still inhabit the seas of tropical climates; and some species that were supposed to be entirely extinct, have recently been discovered living in southern latitudes. More important discoveries of this kind may probably be made, as we know little respecting the state of animal existence at the bottom of the sea, or what monsters

"The deep unfathom'd caves of ocean bear."

"Et quæ marmoreo fert monstra sub æquore pontus."

I am inclined to believe, that the ichthyosaurus, or some species of a similar genus, is still existing in the present seas. About sixteen years since, a large animal was seen for several summers in the Atlantic, near the coast of the United States, and was called the great sea serpent. Its appearance was frequently announced in the public journals, but the existence of the animal was for some time disbelieved in this country. I am informed by Professor Silliman of Yale College, Connecticut, of whom I made inquiry, that many persons who attested the existence of the sea serpent from their own observations, were so highly respectable, both for intelligence and veracity, that their evidence could not be disputed.

I cannot conclude these brief observations on the progressive development of organic life on our planet, without remarking, that if man were recently created, as geologists generally maintain, this circumstance alone affords strong presumptive evidence, to those who admit the doctrine of final causes and of a presiding intelligence, that the ancient condition of the globe, and the changes then in operation, were very different from what we observe at present; or, in other words, that the world was not then prepared by the Creator for the residence of man.

CHAPTER XVII.

ON THE LOWER OR MORE ANCIENT TERTIARY STRATA.

Formation of Tertiary Strata in Lakes or Inland Seas.—Lakes of North America.—Falls of Niagara.—Alternations of Marine and Fresh-water Strata.—Arrangement of the Tertiary Strata in the Paris Basin.—Plastic Clay and London Clay.—Geology of the lower Vale of the Thames.—Remains of Crocodiles and the Nautilus in London Clay.—Molasse of Alpnach in Switzerland, with Coal and Teeth of the Mastodon.—*Calcaire Grossier*, or Coarse Limestone of the Paris Basin, supposed to be of the same Age as the London Clay.—*Calcaire Siliceux*.—Gypsum and Gypseous Marl of the Paris Basin, containing Bones of numerous extinct Species of Land Quadrupeds.—Remarks on their Discovery and Organization by Baron Cuvier.—Marine Sandstone.—Millstone.—Upper Fresh-water Formation.—Fresh-water Formation in the Isle of Wight.—Its remarkable Position.—Mineral Characters of the Strata of the London and Paris Basins compared.—Fresh-water Limestone of Auvergne.

The tertiary formations, comprise all the regular strata of limestone, marl, clay, and sandstone, that have been deposited after chalk. It is only since the commencement of the present century, that they have attracted the notice of geologists: their true nature was before unknown, or they were supposed to be local and alluvial depositions. It is now discovered that tertiary formations are widely spread over many parts of the globe, and are often of considerable thickness.

The first circumstance which indicated that the tertiary beds were distinct from the secondary, was the discovery that many of these beds contain the bones of the higher order of animals, as perfect in their organization, as any of the existing species of land quadrupeds. The tertiary beds were farther remarkable, for presenting frequent alternations of beds containing the remains of marine animals, with other beds that contain exclusively the remains of land animals, and plants, and fresh-water shells: hence the latter beds were denominated fresh-water formations. A more accurate examination of the secondary strata has since discovered, that fresh-water formations occur also among the more ancient strata, but their characters are not so distinctly marked. When the first edition of this work was published, viz. early in 1813, the name of fresh-water formations was scarcely known in England, but the author ventured to offer an explanation of their formation, from what is now taking place in extensive lakes: a similar explanation has since been generally adopted. "The lakes of North America are seas of fresh water, more than 1500 miles in circuit; they are placed at a considerable elevation above the Atlantic, and at different levels. They unite by small straits or rivers, which

have a rapid descent. On some of the rivers are prodigious waterfalls, which are continually enlarging and deepening the passage from one to the other; and will ultimately effect the drainage of the upper lakes. The falls of Niagara are well known; the water is divided by a small island, which separates the river into two cataracts, one of which is 600 yards, and the other 350 yards wide: the height of the fall is from 140 to 160 feet deep. It is estimated that 670,000 tons of water are dashed every minute with inconceivable force against the bottom, and wearing down the adjacent rocks. Since the banks of the cataract were inhabited by Europeans, they have observed that it is progressively shortening the distance of the falls from Lake Erie. When it has worn down the intervening calcareous rocks, the upper lake will become dry land, and form an extensive plain or valley, surrounded by rising ground and watered by a river or smaller lake, which will occupy the lowest part. *In this plain, future geologists may trace successive strata of fresh-water formation, covering the subjacent ancient limestone. The gradual deposition of minute earthy particles, or the more rapid subsidence of mud from sudden inundations, will form distinct beds, in which will be found the remains of fresh-water fish, vegetables, and quadrupeds.*"—1st edition, 1813, pp. 182, 183.

In the frontispiece to the present volume will be seen a bird's-eye view, or map of the country round Niagara, drawn by my eldest son, who passed several days at the falls of Niagara in 1829. In this drawing the accurate proportion of distance is disregarded, in order to bring the several objects into one point of view. The deep chasm formed by the cataract is seen in front, from which the water is issuing into a lower country at Lewiston, nearly on a level with Lake Ontario, into which the river flows. Mr. Joseph Henry, in a topographical sketch of the state of New York, says, "The descent of the country from Lake Erie to Ontario is principally by a step, not at the falls, but at Lewiston, several miles below:" this is the position from which the drawing in the frontispiece was taken. Mr. H. adds, "In viewing the position of the falls, and the features of the country round, it is impossible not to be impressed with the idea, that this great natural raceway has been formed by the continued action of the irresistible current of the Niagara, and that the falls, beginning at Lewiston, have, in the course of ages, worn back the rocky strata to their present site. The deep chasm through which the Niagara passes, below the falls, is nearly a mile wide, with almost perfect mural sides."—*Transactions of the Albany Institute.*

In Mr. Loudon's Magazine of Natural History, March, 1830, there is an account of the falls of Niagara, and of the physical structure of the adjacent country, by my son, Robert Bakewell,

junior. I preferred making the above extract from Mr. Henry's description, as it confirms the general accuracy of the drawing in the frontispiece. Below will be seen a statement of the levels and the extent of the North American lakes.* These lakes may justly be styled seas of fresh water. Though their present surface is considerably elevated above the level of the ocean, the bottom of some of the largest lakes is much below the tide line; and were these lakes situated nearer to the Atlantic, we might easily imagine that after the fresh water had subsided to the sea level, they might be subject to frequent irruptions of salt water, which would produce a change in the nature of the inhabitants of these lakes; or, in other words, would occasion alternations of marine with fresh-water strata, without any change in the relative level of the land and sea.

In England and France, there appears to have been a considerable interval between the deposition of the chalk, and of the lowest beds of the tertiary strata: for the surface of the chalk is deeply furrowed and broken, apparently by the action of torrents, or inundations, and the hollows are filled by the tertiary beds. In some parts of the Continent, however, the line of separation between the secondary and tertiary strata is not so distinctly marked, and they are both elevated together conformably.

The tertiary strata form the outer crust of the globe, and have every where been subjected to erosion from torrents and inundations, that have swept over parts of its surface, and transported the fragments into distant countries or into the ocean. We cannot, from the present localities of the upper strata, determine, with any precision, the boundaries of the inland lakes or seas in which they were deposited. Many of these strata have evidently once extended far beyond their present limits, but have been so completely destroyed, that we can only infer their former existence, by a few remaining detached portions. But could we ascertain the limits of the tertiary fresh-water strata, we should be utterly unable to determine the extent and bounds of the ancient dry land, from whence the lakes collected the fresh water with which they were filled.

---

* From Lake Erie to the falls of Niagara, the distance is 21 miles. From the falls to Lewiston, at the mouth of the chasm, the distance is 7 miles. From Lewiston to Lake Ontario the distance is 7 miles.

	Elevation above the sea. FEET.	Mean depth.	Length. Miles.	Mean breadth.
Lake Superior, . . .	641	900	300	80
Lake Huron, . . .	596	900	200	95
Lake Michigan, . .	600	900	300	50
Lake Erie, ...	565	120	230	35
Lake Ontario, . . .	231	492	180	30

Total quantity of square miles covered by the lakes, 72,930.

In France, the tertiary strata are more widely spread, and many of them more fully developed, than in England: it is indeed scarcely possible to imagine a more distinct display of the series of strata in any class of rocks, than is presented close to the very gates of Paris. In a capital so distinguished for scientific investigation, and possessing so many able and acute observers, it does, indeed, seem extraordinary, that the strata with which they were surrounded, should never have been properly examined until so recent a period, as the early part of the present century. What is daily before our eyes seldom excites attention, or is deemed deserving of much notice; but there was another cause which long prevented the philosophers of Paris from observing the remarkable objects around them. Captivated with the generalizations of Werner, who, it was firmly believed, had unlocked all the hidden mysteries of geology, and comprised in his system all the different formations that composed the crust of the globe, they saw before them a series of strata which had no agreement with any part of the Wernerian classification; hence they could not avoid the painful persuasion, either that the system of Werner was incomplete, or that they were unable to apply it properly. To avoid an acknowledgment so little satisfactory, the geologists of Paris averted their attention, and that of their pupils, from nearer objects, and directed them to the mountains of Germany and Switzerland. Had not another science (comparative anatomy) come to the aid of geology, we might yet have remained unacquainted with the tertiary strata around Paris. At length the number of skeletons of strange and unknown animals discovered in some of the strata, forcibly attracted the notice of that distinguished naturalist, Cuvier, and it was resolved to investigate attentively the geology of the whole district. M. A. Brongniart was associated with Cuvier in the investigation, and in 1811 the result of their labors and observations was given in a work entitled *Essai sur la Géographie Minéralogique des Environs de Paris*,—the most luminous and interesting exposition of local geology ever presented to the world; and from this period we may date the first accurate knowledge of the tertiary strata.

The following extract from the essay of MM. Cuvier and Brongniart, presents a general view of the arrangement of the strata round Paris:—

"The country in which the capital of France is situated, is perhaps the most remarkable that has yet been observed, both from the succession of different soils of which it is formed, and from the extraordinary organic remains which it contains. Millions of marine shells, which alternate regularly with fresh-water shells, compose the principal mass. Bones of land animals, of

which the genera are entirely unknown, are found in certain parts; other bones remarkable for their vast size, and of which some of similar genera (*quelques congenères*) exist only in distant countries, are found scattered in the upper beds. A marked character of a great irruption from the southeast is impressed on the summits (*caps*,) and in the direction of the principal hills. In one word, no country can afford more instruction respecting the last revolutions, which have terminated the formation of the present continents."

Though chalk is the foundation rock of the country, for a considerable extent round Paris, it only rises to the surface in a few situations, being covered by tertiary strata. The total thickness of the tertiary strata over the chalk, as given in an ideal section of the country, is nearly five hundred feet.*

Many of the tertiary beds in the Paris basin are not found elsewhere, and therefore cannot be taken as types of other tertiary formations; and the lower bed, called the plastic clay, is but very imperfectly developed near Paris. In attempting to generalize the tertiary formations, a difficulty presents itself, if we are to class them by their zoological characters; for some of the formations, which contain exclusively the remains of marine animals in certain situations, contain in other situations river or lake shells, with wood and the bones of land animals. It is, therefore, probable, that while the waters in one lake or basin might be saline, those in another lake might be fresh; and two contemporaneous formations may hence contain very different organic remains.

The tertiary strata in England and in the north of France, may be arranged under four divisions: after describing these, the more recent tertiary strata, called by some French geologists Quaternary, will be noticed in the following chapter.

---

* The following ascending series of beds in the Paris basin was first given as a correct account of their succession: more extended observations have proved that No. 3, or the Calcaire siliceux, is sometimes interstratified with the Calcaire grossier.

1. Plastic Clay and Lower Sand.
2. Calcaire Grossier.
3. Calcaire siliceux and Sandstone.
4. Gypseous Marl.
   Gypsum with Bones.
   Upper gypseous Marl.
5. Sandstone and Sand without Shells.
   Upper Marine Sandstone.
   Millstone without Shells.
6. Fresh-water Limestone, including Marls and Millstone, with Fresh-water Shells.
7. Alluvial Soil, ancient and Modern, including Pebbles, Pudding Stone, Black Earth (*les marnes argilleuses noires*) and Peat.

TERTIARY FORMATIONS.

1. Lower Marine Beds, - Sometimes intermixed with fresh-water beds.
   - *a.* Argillaceous and sandy deposits, Plastic Clay, Sand, London Clay. — *Argille et Grès tertiaires à lignites.*
   - *b.* Lower Marine Limestone. — *Calcaire grossier; et Calcaire siliceux.*
2. Lower Fresh-water Beds, - Sometimes intermixed with Marine.
   - *a.* Marl.
   - *b.* Gypsum.
3. Upper Marine Formation.
   - *a.* Sand, Sandstone and Millstone without Shells.
   - *b.* Sandstone with Shells.
4. Upper Fresh-water Formation.
   - *a.* Limestone, - - - With fresh-water Shells.
   - *b.* Siliceous Millstone, - -

The tertiary strata, supposed to be more recent, are nowhere observed covering the above formations, because they were deposited in detached seas or lakes: the evidence of their being more recent than the strata in the Paris and London Basins, rests on the species of fossils they contain, being in a large proportion analogous to existing species.

Plastic Clay and London Clay.—These, with the various associated beds of sand, may properly be regarded as one formation, of which the Plastic clay is the lowest member, resting on chalk. Near Paris the Plastic clay is a very thin bed, but in the south of France it acquires a great degree of thickness, and appears to comprise the upper argillaceous beds, or what we call the London clay: it is remarkable for the vegetable fossils and beds of lignite, which it frequently, but not invariably contains. In England, in the lower beds of this formation, there are found beds of imperfect wood coal; but both in the plastic clay and the London clay, remains of marine animals are chiefly prevalent, though intermixed with some fresh-water shells; whereas, on the Continent, beside the great quantities of fossil wood and wood coal found in the same argillaceous beds, there are numerous remains of fresh-water shells, which render their title to be denominated marine formations more than doubtful. The beds of sand are sometimes of considerable thickness. By many geologists, it is maintained that the beds of soft sandstone (called *Molasse*,) and of sandstone conglomerate, (called *Nagel flue*, in Switzerland,) belong to this part of the tertiary formations. That

some of these beds may be tertiary I will not deny; but I am fully convinced, that many beds called molasse, in Savoy, are covered by the Jura limestone and oolites, having repeatedly seen them in contact, and got specimens from each bed at the line of junction.*

The bones of horses, with the tooth of an elephant, have been found in a bed of unctuous clay, resting on chalk, near Margate; but as the clay is superficial, it may be a diluvial formation.

In France, near d'Auteuil, and south of the Dordogne, according to Humboldt, bones of vertebrated land animals are found in a formation resting on chalk, analogous to the plastic clay. Baron Cuvier says, however, that he has not discovered the bones of land quadrupeds in any strata below the *calcaire grossier* which covers the plastic clay. But neither the plastic clay nor the gypsum bed of Paris, can be taken as types of the tertiary strata in other countries.

The London clay is placed over the plastic clay and sand, and is, in fact, an upper member of the great arenaceous and argillaceous formation that covers chalk. Some geologists attempt to

---

* As the opinions of geologists have been much divided respecting the molasse, or soft sandstone of Switzerland and Savoy, I shall here insert some observations upon it, given in the first volume of my Travels in the Tarentaise.

"The outer calcareous mountains on the western side of Savoy, all rest upon an immense formation of soft sandstone (molasse,) and are interstratified with it, and, so far from this sandstone being more recent than the limestone (as Saussure supposed,) it constitutes a considerable part of the bulk of these mountains that are called calcareous. In the valley of les Echelles, the immediate junction of the limestone with the sandstone may be seen soon after entering the valley from the archway. This vast wall of limestone, nearly one thousand feet in thickness, rests upon a mass of sandstone of unknown depth; there is very little dip where the first junction is seen, but about a mile below, you meet with the limestone again in conjunction with the sandstone, and thrown into a vertical position. The workmen that I met with near the mouth of the gallery said they always found sandstone below the limestone, and they considered it as the lowest bed in the country: but this is obviously a mistake. The sandstone, or molasse, on which the limestone in this part of Savoy reposes, or which is subordinate to the limestone, is composed of smallish grains of quartz and chlorite, pretty equally mixed. In the sandstone of les Echelles, which I got from its junction with the limestone, there were some particles of rose quartz and mica. It scratched glass strongly when rubbed upon it; but when put into a dilute muriatic acid, it effervesced violently, and became friable, owing to the solution of the calcareous cement, by which it appears, from this experiment, to be agglutinated. The molasse, which is interstratified with limestone and associated with coal on the lake of Annecy, also effervesced; but, the particles being smaller, it appeared nearly homogeneous when examined without a lens. It has been recently stated, that the molasse of the Alps belongs to the same formation, as the sandstone above chalk near Paris. There may be sandstone of that formation in the canton of Berne; but the molasse or sandstone in this part of Savoy, I am well convinced, is a member of formations that are lower than chalk. It is possible, however, that beds of this molasse may have been worn down during the great destruction of the strata, that has evidently taken place since they were deposited, and from the debris of this sandstone, upper beds may have been formed covering strata that are above chalk. The molasse which covers the bones and teeth of the mastodon and other large mammalia, near Alpnach, nearly resembles that in this part of Savoy; but the particles are smaller, and more intimately mixed." p. 176.

identify the London clay with the beds of calcaire grossier, and of gypsum, in the Paris basin, but their mineral characters are most essentially different. By attempting to force an agreement with artificial classifications, where it does not exist, we mystify what is clear and simple, and retard the progress of knowledge.

The uppermost bed of the London clay is of a reddish brown color, and is more arenaceous than the lower beds: the color of the lower beds varies from a bluish lead color, to a blackish brown; they are often considerably indurated, and have somewhat of a slaty structure. The thickness of the London clay varies from one hundred to four hundred feet or more: this variable thickness is occasioned by the upper beds, which form the surface of the land in the Vale of Thames, having been more excavated in some parts than in others.

As the London clay and plastic clay and sand, taken together, equal or exceed in thickness the beds of plastic clay, calcaire grossier, and gypsum in the Paris basin, the London clay may properly be regarded not as identical with the calcaire grossier and gypsum, but as their geological equivalent. While the beds of limestone and gypsum were depositing in the Paris basin, the London clay might be deposited in the London basin; and this may explain why many species of marine shells in the London clay, are similar to those found in the calcaire grossier; but we nowhere discover the astonishing variety of species that occur in some of the strata of the calcaire grossier; nor have any bones of land quadrupeds, similar to those in the Paris basin, been found in the London clay. The two sides of the trough or basin in which the London clay and plastic clay were deposited, are formed on the north, by the range of chalk hills in Hertfordshire, and the adjacent counties, and on the south by the range of chalk hills in Surrey and Kent.

The relative geological position of the chalk, the plastic clay and sand immediately upon it, and the upper beds of London clay covering the Vale of Thames, is represented in a small section at the bottom of the map of England. (Plate VI.) In some parts of the Vale of Thames, as at Hampstead, north of London, and near Cobham, in Surrey, the London clay rises into hills three hundred feet above the Vale of Thames, and is capped by a bed of sand, which has received the name of the upper marine sand. *a, a,* chalk; *b, b,* plastic clay; *c, c,* London clay; *d, d,* marine sand. From this small section the geological student may form some idea of the devastating effects of mighty inundations, which have swept over the surface of the globe, and carried away considerable portions of the upper beds. The marine sand, *d, d,* which forms isolated caps on several of the hills in the Vale of Thames, was probably part of one continuous bed, which has been excavated with a portion of the subjacent London clay;

such excavations and denudations are common phenomena in almost every country.

Balls of imperfect ironstone, called *septária* (of which Parker's cement is made,) are common in some parts of the London clay; branches and stems of trees, penetrated by the *Teredo navalis*, are found in it, and a species of resin, to which the name of *retin-asphaltum* was given by Mr. Hatchett. Remains of turtles have been dug out of this clay at Highgate and Islington. Some bones of a crocodile were discovered by Mr. Parkinson, who considers this as a solitary instance of the occurrence of the remains of these animals in the London clay. In 1830, the head of a crocodile was found by E. Spencer, Esq. of Highgate, in the London clay in the Isle of Sheppey, of which the annexed cuts give a correct representation.* The first is an outline, being

a side view of the upper jaw and teeth. The second represents a front view of the head, with the two small cavities for the lobes of the brain, and the larger cavities for the orbits of the eyes.

The length of the head, when entire and clothed with scales and muscles, must have been about one foot: hence we may infer,

* This head is given in Buckland's B. T., Pl. 25, but by mistake is called original, having before appeared in the fourth edition of this work.

that the entire length of the animal was about six feet. Whether this was the head of a young animal, or of an adult of a small species, cannot, perhaps, be determined. From the rare occurrence of the bones of saurian animals in the tertiary strata, we may infer, that these animals whose remains are so abundant, and of such large magnitude, in the secondary strata, had nearly disappeared in northern latitudes, at the epoch when the tertiary strata were deposited.

The teeth and tusks of elephants have been discovered in many situations, in what is supposed to have been London clay, but which may have been a covering of diluvial clay; for the patches of diluvial gravel that are spread over many parts of the Vale of Thames, frequently contain the remains of elephants.* Ammonites and belemnites, and many genera of testaceous animals, that have left their remains in chalk and the lower strata, appear to have been extinct before the deposition of the London clay. Nautilites are, however, found in it, similar to the species inhabiting the Indian Ocean, and bivalve and univalve shells are so numerous, that it would be difficult to select any particular species, as peculiarly characteristic of this formation. The shells mostly belong to genera inhabiting our present seas; yet slight variations of form may be perceived, which have induced naturalists to regard them as distinct from living species.

The springs that rise in the London clay are generally impregnated with sulphate of iron and sulphate of lime, and some of the springs contain sulphate of magnesia; the quality of the water, however, varies much in different situations, and at different depths. To obtain soft water, it is necessary to bore or sink through the London clay to the sand above the chalk, and sometimes into the chalk itself.† The London clay and the under beds have been perforated to the depth of three or four hundred feet in some situations, before good water could be obtained; when the stratum is pierced which holds the best water, it rises almost immediately, and sometimes overflows the surface. This admits of an easy explanation, by referring to the section of the Vale of Thames. (Plate VI.) The water which enters the edges

* In clearing away the bed of gravel on the north side of the Regent's Park, the tusks of elephants were found, but in a mouldering state, in 1818.

† At the village of Wilsden, three miles northwest of London, the boring for water was made two hundred and eighty feet into the clay, and seventy-five feet below it into the chalk, when the water immediately rose to within thirty-five feet of the surface. Chalk rocks, and other calcareous rocks in which the strata are divided by fissures that are not filled with clay, always contain water in the fissures when the strata dip under the surface of the ground, or when they are covered by argillaceous beds. This is also the case with coal strata; and the presence of water is necessary to keep the coal in good condition. If the water be entirely drained from a bed of coal a considerable time before it is worked, the quality of the coal is much deteriorated. This may be occasioned by air penetrating the fissures, and promoting the decomposition of pyrites in the coal.

of the porous strata, say at x, x, descends to the lowest part of the trough or basin, and when perforated, would rise to near the level of x, x, were the strata deposited in a circular basin, the edges of which rose on each side from the bottom of the Vale of Thames; but the strata are deposited in a longitudinal basin or trough, between the chalk hills of Hertfordshire and Surrey, and the river Thames cuts through the porous edges of the strata below Greenwich, so that the water being there let out, can seldom rise in wells, much above the high-water mark. Were it not for this, we might have natural *jets d'eau* of considerable height and magnitude in all the squares of London, to cool and refresh the air during the summer months, and supply the inhabitants in the vicinity with salubrious water. In order to preserve the water pure, that is obtained from chalk or the sand over chalk, it is necessary to line the inside of the wells, or to put down tubes, to prevent the water from the London clay, intermixing with the pure water from below.

As the plastic clay and London clay contain wood coal or lignite, which is supposed to be characteristic of these beds, probably the strata with wood coal at Alpnach (see Chap. VIII,) may be regarded as belonging to a similar epoch. Some French geologists would place these strata still higher in the tertiary series. The strata at Alpnach are peculiarly remarkable for containing the remains of the narrow-toothed mastodon, and of other mammalia, at the depth of nearly three hundred feet from the surface. The foregoing cut is taken from a drawing of one of these teeth in the

possession of the late Professor Meisner, of Berne, who also gave me specimens of the strata below which the tooth was found.

It is deserving notice, that teeth almost exactly similar, were found on the volcano of Imbaburra in the Andes, which is ten thousand feet above the level of the sea. I have one tooth in my possession from thence, purchased at the sale of the late M. Faujas de St. Fond, of which the preceding cut may also serve as a correct representation.

The strata at Alpnach consist of the following beds, in a descending series:—

	Feet.	Inches.
1. Light grey sandstone - - - -	24	0
2. Light grey limestone like Jura limestone	24	0
3. Different beds of Molasse or soft sandstone	227	0
4. Light grey sandstone with mica, like No. 1.	6	0
5. Light grey argillaceous limestone - -	1	6
6. Bituminous shale in layers - - -	7	0
7. Stinkstone, a bituminous limestone with bones and river shells, the roof of the coal	1 to 2 feet.	
8. Coal - - - - - - - -	0	6 Inches.
9. Bituminous schist - - - -	0	6 to 8
10. Coal - - - - - - -	2	0
11. Bituminous clay - - - - - -	6	0
12. Molasse and sandstone - - - - -	66	0

The bituminous strata, and shaly limestone, possessed all the characters of beds in the regular coal formations in England: probably the fetid quality of the limestone No. 7 was derived from the abundance of animal matter which it might contain. No. 2 is subcrystalline, and bears a near resemblance to mountain limestone in its mineral characters.

Above the London clay there is no calcareous formation, except in the Isle of Wight; but in the Paris basin there are two, of which the lowest is called *calcaire grossier*.

Le calcaire grossier, or coarse limestone of Paris, is deposited upon the plastic clay, as the latter is upon the subjacent chalk: between the plastic clay, however, and the *calcaire grossier*, there is a bed of sand; but geologists are not determined, to which of the two formations it belongs. The *calcaire grossier* differs in its quality in the different beds, but it may be described generally as a yellowish earthy limestone, which bears some resemblance to Portland stone, in its fracture, texture, and color; but it is not oolitic. The strata of limestone, alternate with argillaceous marl and shale, and with calcareous marl.

The lowest bed of *calcaire grossier* is soft, and much intermixed with green particles and sand; it contains a great number of the fossils called nummulites, on account of their being flat and round, and resembling in shape a small coin. The shells in this bed are

in high preservation. In the beds immediately above, called the middle beds, there are a prodigious number of marine shells, and also the stems and impressions of leaves of plants that are not marine. In the lowest and middle beds of the *calcaire grossier*, no less than six hundred different species of shells are found.

In the upper part of the *calcaire grossier*, the strata are several feet thick, and yield a hard coarse grained and durable limestone: it is from these strata that the best building stone is procured. It is often nearly filled with shells of the genus *cerithium*, and has hence been sometimes called *calcaire à cerites*.

Between the strata of building stone, there often occur thin strata of flint or chert: in some parts these siliceous strata enlarge into thick beds of chert (*silex corné*,) or into beds of sandstone containing marine shells; in the beds of this sandstone, at Pierre-laie, fresh-water shells have been discovered, mixed with numerous marine shells. The total thickness of the beds of *calcaire grossier*, near Paris, is about ninety feet.

No beds of limestone resembling the *calcaire grossier* of Paris, are found in the tertiary strata of England. The *calcaire grossier* in the departments of La Dordogne and La Gironde, and other parts of France, presents a considerable difference from that in the Paris basin. In Hungary, extensive strata of the *calcaire grossier* have been described by M. Beudant; they are in every respect analogous to the strata in the Paris basin, both in their mineral and zoological characters. The lower beds also are intermixed with shelly sand and green particles, which bear a close resemblance to the shelly depositions in the plain of Lombardy. M. Humboldt thinks he discovered a formation similar to the *calcaire grossier* in some parts of South America.

Calcaire siliceux is composed of limestone, sometimes grey and compact, and sometimes tender and white; it is penetrated by silex in every direction, and in all its parts. According to the early opinion of M. Brongniart, the *calcaire siliceux* occupies the place of the *calcaire grossier*, where the latter is wanting; others regard it as an upper formation. Some of the beds of the *calcaire siliceux* furnish mill stones, and contain river shells. In this bed, the siliciate of magnesia was discovered by M. Brongniart. The siliceous infiltrations sometimes form plates of chalcedony, and mammillated concretions of chalcedonic chert, colored red, violet, and brown.

Gypseous Marl and *Gypsum.*—This remarkable formation occurs in detached hills along the course of the rivers Marne and the Seine; it is supposed to have originally extended as one continuous bed from east to west, twenty-five leagues in length, and eight in breadth: its greatest thickness is about two hundred feet.

The gypsum formation consists of alternating beds of gypsum and argillaceous and calcareous marl, which are regularly arran-

ged, and preserve the same order of succession wherever they have been examined. The gypsum forms three distinct masses. The lowest consists of thin strata of gypsum, containing crystals of selenite, which alternate with strata of solid calcareous marl, and with argillaceous shale. The middle is like the lowest mass, except that the strata of gypsum are thicker, and the beds of marl are not so numerous: it is chiefly in this mass that fossil fish are found. The uppermost mass is the most remarkable and important of all: it is in some parts more than seventy feet thick; there are but few beds of marl in it; the lower strata of gypsum in this mass have a columnar structure: the gypsum is pure, and finely granular; it has a light yellowish brown color, which might perhaps more properly be called a dirty white. In this upper mass of gypsum, the skeletons and scattered bones of birds and unknown quadrupeds are discovered: sometimes they are found in the solid gypsum, and sometimes in the marl that separates the beds. Remains of turtles and crocodiles have also been found in the same strata. It is to the indefatigable and enlightened labors of Baron Cuvier, that we are indebted for a knowledge of the different genera of remarkable land quadrupeds, belonging to a former world, found in the gypsum quarries; they differ from any genera of living animals. These land quadrupeds were herbivorous: they belong to the order which Cuvier has denominated *Pachydermata*, or thick-skinned non-ruminant animals. One of the genera, called *Palæotherium* (or ancient animal,) appears to bear some relation to the rhinoceros, the hippopotamus, and the horse, and, in some respects, to the pig and the camel.

Of this genus there are eleven or twelve species; five of them have been found in the Paris gypsum. The largest was the size of a horse, but its form was heavy, and its legs thick and short; its grinders resemble those of the rhinoceros and the daman;* it has six incisive and two canine teeth, like the tapir, and, like that animal, had a short fleshy trunk: it had three toes on each foot, and is supposed to have inhabited marshy ground, and to have lived on the roots and stems of succulent marsh plants. One of the species, however, possessed the size and the light figure of the antelope, and is supposed to have browsed on aromatic plants, or the buds of young trees, in dry situations, like other light herbivorous animals. Probably, says Cuvier, it was a timid animal, with large movable ears, like those of the deer, which could apprise it of the least danger: doubtless its skin was covered with short hair; and we only want to know its color, in order to paint it as it formerly lived in the country where, after so many ages, its bones have been dug up.

* An African quadruped, the size of a rabbit, but closely resembling the rhinoceros.

One species of the *palæotherium* was not larger than a hare.

The *Anoplotherium*, or animal without defensive teeth, has only been found in the gypsum quarries near Paris.* It has two very distinctive characters: the feet have only two toes, which are separated the whole length of the foot; the teeth, of which there are six incisive in each jaw, a canine tooth of the same height, and six molares or grinders, all form a continued series without any interval, which is the case with no other known quadruped. The most common species is of the height of a boar, but much longer. There are remains of other animals, in the same quarries, allied to the anoplotherium, but which differ in the form of their teeth. The bones of six species of birds have been discovered in these quarries, and also the remains of a few carnivorous animals, allied to the dog and the weasel. It is remarkable, that in the middle of the gypsum formation, and throughout the greater part of it, we find the remains of land animals and of fresh-water fish and shells; but near its upper and lower limits, both in the gypsum and the gypseous marl, the fossils are those of marine animals. A bed of green marl, which may be very distinctly traced near the termination of the upper mass of gypsum, separates the fresh-water from the sea shells, and in the lower part of the gypsum formation, marine shells are found in the gypsum itself.

It may be useful to those strangers who visit Montmartre for the first time, to state, that this thin green bed, which can be distinctly seen and traced, may serve them as a key to the geology of the place, as it separates all the lower marine and fresh-water formations from the upper.

The gypsum of the Paris basin was probably deposited in an extensive lake, on the borders of which the land-animals, whose remains are discovered in it, flourished and perished. Some of them appear to be formed for swimming, or living much in the water, like the otter or water rat. Whether the water in this lake was salt or fresh, is by no means certain; though M. Brongniart thinks that a single fresh-water shell found in the gypsum would decide the question: but this opinion, however high the authority of so distinguished a naturalist and geologist may be, cannot, I conceive, be maintained; for in some of the beds we meet with a mixture of marine and fresh-water shells,—and, in this case, who shall determine whether such beds are of marine or fresh-water origin? The intermixture of shells clearly shows, that they have been transported from their native situations, or that marine and fresh-water mollusca may live in the same estu-

---

* The skeletons and restored forms of the palæotherium and anoplotherium, taken from Cuvier, are represented Pl. 2 and 3, Vol. 2, Buckland's B. T.

ary or lake, if the water be brackish, which is confirmed by recent observations and experiments.

The fossil bones found in the gypsum quarries near Paris are light and porous, and appear to have been scarcely penetrated by gypsum: this is very remarkable; for if we suppose the gypsum to have been held in solution by water, like the sulphate of lime in recent springs, it seems extraordinary that it should not have penetrated into the pores of the bones. I am not aware that the circumstance has before been noticed by geologists, but I think the state of the bones proves, that they were rapidly enveloped by the gypsum, before the animal matter in the pores was decomposed; and also that the gypsum was speedily consolidated. The same observation would apply to the bones of land animals, I found in the fresh-water limestone under the volcanic mountain of Gergovia, in Auvergne; the state of these bones was similar to those in the Paris gypsum.

Baron Cuvier was the first naturalist who successfully applied the knowledge of comparative anatomy to ascertain the forms of vertebrated fossil animals. The publication of his *Recherches sur les Ossèmens Fossiles* may be regarded as an epoch in geology: since that time, many other important discoveries respecting fossil quadrupeds have been made. It will not, therefore, be deemed irrelevant to our subject, to insert the very interesting account he has given of his own feelings, when he first became able to arrange the bones of each genus and species of unknown animals found in the gypsum quarries near Paris:—"When the sight of some bones of the bear and the elephant, twelve years ago, inspired me with the idea of applying the general laws of comparative anatomy to the reconstruction and the discovery of fossil species,—when I began to perceive that these species were not perfectly represented by those of our day, which resembled them the most,—I did not suspect that I was every day treading upon a soil, filled with remains more extraordinary than any that I had yet seen; nor that I was destined to bring to light whole genera of animals unknown to the present world, and buried for incalculable ages at vast depths under the earth. It was to M. Veurin that I owe the first indications of these bones furnished by our quarries: some fragments which he brought me one day, having struck me with astonishment, I made inquiries respecting the persons to whom this industrious collector had sent any formerly: what I saw in these collections served to excite my hopes and increase my curiosity. Causing search to be made at that time for such bones in all the quarries, and offering rewards to arouse the attention of the workmen, I collected a greater number than any person who had preceded me. After some years I was sufficiently rich in materials to have nothing further to desire; but it was otherwise with respect to their arrangement and

the construction of the skeletons, which alone could conduct me to a just knowledge of the species. From the first moment, I perceived that there were many different species in our quarries; and soon afterwards, that they belonged to various genera, and that the species of the different genera were often of the same size; so that the size alone rather confused than assisted my arrangement. I was in the situation of a man who had given to him, *péle méle*, the mutilated and incomplete fragments of a hundred skeletons, belonging to twenty sorts of animals, and it was required that each bone should be joined to that which it belonged to. It was a resurrection in miniature; but the immutable laws prescribed to living beings were my directors.* At the voice of comparative anatomy, each bone, each fragment, regained its place. I have no expressions to describe the pleasure experienced, in perceiving that as I discovered one character, all the consequences more or less foreseen of this character, were successively developed. The feet were conformable to what the teeth had announced, and the teeth to the feet; the bones of the legs and the thighs, and every thing that ought to reunite these two extreme parts, were conformable to each other. In one word, each of the species sprung up from one of its elements. Those who will have the patience to follow me in these memoirs, may form some idea of the sensations which I experienced, in thus restoring by degrees these ancient monuments of mighty revolutions. This volume will afford much interest to naturalists, independent of geology, showing them, by multiplied examples, the strictness of the laws of co-existence, which elevate zoology to the rank of the rational sciences, and which, leading us to abandon the vain and arbitrary combinations that had been decorated with the name of *systems*, will conduct us at last to the only study worthy of our age—to that of the natural and necessary relations, which connect together the different parts of all organized bodies. But geology will lose nothing by this accessary application of the facts contained in this volume;

---

* In the following passage Cuvier has more fully explained what he denominates "the immutable laws prescribed to living beings:"—"Every organized being forms a whole and entire system, of which all the parts mutually correspond and cooperate, to produce the same definite action by a reciprocal reaction: none of these parts can change, without a change of the others also. Thus, if the intestines of an animal are organized in a manner only to digest fresh flesh, it is necessary that his jaws should be constructed to devour the prey, his claws to seize and tear it, his teeth to divide the flesh, and the whole system of his organs of motion to follow and overtake it, and of his organs of sense, to perceive it at a distance. It is necessary, also, that he should have seated in his brain, the instinct to hide himself and spread snares for his victim. Such are the general conditions of a carnivorous regimen: every carnivorous animal must infallibly unite them; without them, the species could not subsist; but under these general conditions, there are particular ones with respect to the size of the species, and the abode of the prey, for which each animal is disposed."

and thus the numerous families of unknown beings, buried in the most frequented part of Europe, offer a vast field for meditation."

Marine Sand and *Sandstone.*—In the Paris basin this formation covers the gypsum, or where that is wanting, it rests on the *calcaire grossier*. The marine sand and sandstone is divided into two beds; the lower is without shells *in situ*, though some broken fragments occur in it. This sandstone is frequently composed of grains of transparent pure silex, and occasionally contains small scales of mica. In some situations this sandstone is penetrated by calcareous infiltrations. In other situations there are balls and masses of much harder sandstone, which are used for paving stones in Paris, but they are not durable. At the forest of Fontainebleau in France, the thickness of this sand and sandstone, exceeds one hundred and seventy feet; the sandstone occurs in loose blocks and irregular masses, and sometimes is distinctly stratified. In some parts the sand is so pure, that it is used in making the finest glass; in other parts the quantity of calcareous earth is so large, that it assumes the form of calcareous crystals. There is no stratum of this marine sandstone in England, but detached blocks of similar stone, called grey weathers, are scattered over some of the southern counties, and some of the large stones at Stonehenge are of the same kind. South of Nemours, in passing from Lyons to Paris, I observed masses of this sandstone, loosely imbedded in sand, at considerable elevations, and as the sand becomes washed away, these masses fall out, and are scattered over the lower ground; in this manner the occurrence of the blocks of grey weathers may be accounted for: they are the remains of a formation of upper sandstone, which has disappeared in England.

The Upper Marine Sand and *Sandstone* contains numerous marine shells: it has frequently a reddish color; it is a thin bed, compared with the sandstone without shells, and is not of general occurrence. It may be studied at Montmartre. Whether any analogous beds have been found in England, is not well ascertained, but the beds of sand at Bagshot Heath, and in other situations resting on London clay, have been generally classed with the upper marine sandstone of the Paris basin. The Bagshot sands consist, according to Mr. Warburton, of ocherous sand, foliated green clay, with green sand, and various colored marls; a few marine shells have been found in this sand.

The marine sand and sandstone is in some parts covered with a bed of argillaceous and ferruginous marl, from three to fourteen feet in thickness, in which are imbedded irregular layers of compact silex or hornstone, full of pores and cavities, which give it a corroded and cellular appearance. It is this asperity of surface, that renders this stone peculiarly fitted for mill stones. The sub-

stance of mill-stone, when unmixed, is pure silex; it has generally a reddish or yellowish color, but that of the best quality is nearly white. All the best mill stones used in England are brought from this bed, and are known by the name of Burrh stones. There are no shells or organic remains in this bed.

Upper Fresh-water Formation.—This formation, though extensively spread over many parts of the Continent, is scarcely known in England: it occurs in the Isle of Wight. In the Paris basin it covers the other tertiary strata, and is itself covered with vegetable soil. The upper fresh-water formation is so called, because all the shells it contains are analogous to fresh-water shells: it consists principally of calcareous earth, and siliceous earth, sometimes separated, and sometimes intermixed. Calcareous earth, in the state of pure limestone, is the most common: large masses of fresh-water silex are more rare. The silex occurs sometimes as a pure translucent flint, and is sometime opaque, with a resinous fracture; sometimes it approaches to the state of jasper, and sometimes it has all the characters of millstone.

Fresh-water limestone, in the vicinity of Paris, has generally a greyish white, or a yellowish color; it is sometimes as tender as chalk, and sometimes hard and compact, with a fine grain and conchoidal fracture: in the latter state it is brittle, and breaks into sharp-edged fragments like flint. Some of this limestone, at a distance from Paris, particularly that of Château Landon, presents the character of a transition marble, and will receive a fine polish. Several of the basins with *jets d'eau*, in the gardens of the Tuilleries, are made of this marble. Many of the harder fresh-water limestones, however, rapidly disintegrate on exposure to air and moisture, and fall to the state of marl, and are used as manure. This formation is characterized by containing exclusively fresh-water and land shells, similar to what are found in the neighboring marshes; they belong to a small number of genera or species, being chiefly lymnites, planorbi, turbinated shells, (allied to *cerithea*,) cyclostomæ, and helices.

Having described the tertiary strata round Paris and London, I shall proceed to the tertiary strata in the Isle of Wight, which contain many beds that are wanting in the London strata. The formations of the north of France and of England, do not, as it was once imagined, compose the whole of the tertiary deposits, but only the lower and middle parts. A brief account of the tertiary formations in other countries, will be subsequently given.

For the first accurate account of the tertiary strata in England, we are indebted to Mr. Webster, who published in vol ii. of the Transactions of the Geological Society of London, a description of these strata in the Isle of Wight, and their connexion with the subjacent chalk. The chalk covered by the London clay, passes under the channel, called the Solent, and rises in the mid-

dle of the island, forming a range of hills which extends from Culver Cliffs on the east, to the Needles on the west. Here we meet with a remarkable derangement of the beds of chalk, and of the superior strata; part of the strata of this range of hills are thrown into a position nearly vertical, from the western to the eastern side of the island, evincing the action of a mighty disturbing force—a force which can be so often observed to have broken or upheaved the secondary and tertiary strata, in the vicinity of the Alps. Evidence of the same dislocation of the strata, extends from the Isle of Wight into Dorsetshire.

The whole thickness of the beds at Alum Bay, in the Isle of Wight, which are nearly vertical, according to Mr. Webster's measurement, is not less than three thousand feet, comprising fourteen hundred and eighty-one feet of strata above the chalk, about nine hundred and eighty-seven feet of chalk, and five or six hundred feet of lower strata. Farther south, the strata under chalk are seen in their original horizontal position; and on the northern side, there are hills composed of horizontal strata of fresh-water limestone. That the vertical strata were originally horizontal, may be inferred from their generally occuring in that position in the southern counties, and is rendered certain from the following circumstance described by Mr. Webster. In one of the vertical beds consisting of loose sand, are several layers of flints, extending from the bottom to the top of the cliff. "These flints have been rounded by attrition, are from an inch to eight inches in diameter, and appear to have belonged to the chalk. Now it is inconceivable that these flints could have been originally deposited in their present position: they distinctly point out the former horizontal direction of this series. There are no signs of partial disturbance in these beds; the whole appears therefore to have been moved together."

Closely adjoining the vertical strata, occurs a series of horizontal strata, which are distinctly visible in a hill called Headon:—these strata consist of an alternating series of fresh-water and marine deposits, bearing a striking similarity in their fossil contents, to the fresh-water strata in the vicinity of Paris. According to Mr. Webster, they consist of the following depositions, in a descending series.

1. A calcareous stratum, containing only fresh-water shells.—*Upper fresh-water.*

2. Greenish marl with marine shells.—*Upper marine.**

* This bed is now supposed to have been deposited during a temporary irruption of the sea, and is not of sufficient importance to divide the fresh-water limestone of Headon hill into two formations. Such interpositions of marine strata, are frequent in some parts of the fresh-water formations of the Paris basin. But whether we arrange the strata at Headon into one or two fresh-water formations, it no way detracts from the correctness or value of Mr. Webster's original observations.

3. Marl with fresh-water shells.—*Lower fresh-water.*
4. Dark blue clay without shells.—*Lower marine.*

Thus we have over chalk four distinct formations. No. 4. A lower marine formation, which includes the London clay. No. 3. A lower fresh-water formation. The strata of this formation consist of sandy, calcareous, and argillaceous marl; some of them appear to be formed almost wholly of the fragments of fresh-water shells, without any mixture whatever of marine shells. "From the quantity of these shells, and the regularity and extent of the strata, we are compelled," says Mr. Webster, "to admit that the spot where they now are, was once occupied by fresh water, in which these animals existed in a living state." Over this fresh-water, occurs an upper stratum, No. 2, which contains a vast number of fossil shells, wholly marine. Again, over this marine formation, in the same hill, is a calcareous stratum, No. 1, fifty-five feet in thickness, every part of which contains fresh-water shells in great abundance, without any admixture of marine exuviæ. Many of the shells are in high preservation, and the animals must formerly have lived in the very spots where they now are, the shells being so fragile, that they could not have been removed from their original situation without breaking. Part of the stone of this formation is very hard and compact, and has long been extensively used for building stone. This stratum appears to have extended over the whole of the northern part of the Isle of Wight, but it has not yet been discovered in any other situation on this side of the water: it may be considered as the latest formation of rock we are acquainted with in England, and agrees in many of its mineralogical characters, and the fossils it contains, with the fresh-water limestone, *calcaire d'eau douce*, in the vicinity of Paris; they are different from any other known rock."

Nowhere have there been discovered, in the series of fresh-water strata in England, any traces of the remarkable beds of gypsum containing bones of unknown genera, and species of quadrupeds, similar to the gypsum of Montmartre. A few bones of an anoplotherium and of a palæotherium have, however, been found in the fresh-water limestone at Binstead, on the eastern side of the Isle of Wight.

Dr. Buckland has pointed out many localities west of the limits of the London clay, where patches of the lower beds occur. These patches indicate, that what is called the London basin, and the basin of the Isle of Wight, were once continuous, and that their continuity was broken by the upheaving of the chalk, which, in several parts, had lifted up the portions of tertiary strata that still remain.

Bagshot Sand.—It has before been stated, that the beds of loose sand that cap the London clay at Bagshot, and in other parts of the Vale of Thames, have been supposed to represent the upper

marine sand and sandstone of the Paris basin; but for this opinion there appears to be no very satisfactory foundation. The sand on the top of Hampstead Heath, is similar to that of Bagshot, but it contains irregular layers of flint pebbles, and, in some parts, a bed of large rounded flints is interposed between the London clay and the sand. The beds of sand in Norfolk, called *crag*, appear to be the most recent of the English tertiary strata, and will be noticed in the following chapter.

On comparing the tertiary strata of the London and the Paris basins, we shall find a very marked difference in the mineral composition of the beds. The strata of the London basin, excluding those of the Isle of Wight, are all marine sedimentary depositions, formed originally of mud and sand. The strata of the Paris basin, beside the marine and fresh-water limestones, comprise beds of considerable thickness, which have evidently been formed by chemical solutions; such are the thick beds of sulphate of lime that have probably been formed by powerful eruptions of water, containing sulphuric acid, which has dissolved a portion of the calcareous beds, and buried the remains of animals in depositions of gypsum. The balls and concretions of hard earthy sulphate of strontian, so abundant in the green marls over the gypsum beds, are truly remarkable; strontian, either combined with carbonic or sulphuric acid, being so extremely rare in transition and secondary formations. The siliceous depositions of translucent flint, and of millstone, both in the fresh-water and marine formations, are chemical formations, and the grains of silex, which compose the sandstone at Fontainebleau, and in other parts of the Paris basin, are so pure, crystalline, and free from admixture with other minerals, that they have, with some probability, been described as of chemical origin, or as granular depositions from siliceous solutions. The beds in the London basin contain the remains of marine animals, and are therefore regarded as having been deposited in the sea, but they contain also fossil wood, penetrated by the teredo, and the remains of a few fresh-water animals; hence it is evident that there was dry land in the vicinity. In the Paris basin, the fresh-water formations are of such vast extent and thickness, that they must have been deposited in a lake or estuary of nearly one hundred miles in length, and thirty miles in breadth, but we can trace no indications of the boundaries of the vast island or continent, from which the fresh water flowed, at different periods, to fill a lake of such magnitude.

The fresh-water limestone of Auvergne, is supposed to be of the same epoch as the fresh-water formations in the Paris basin, but the limestone of Auvergne is unmixed with marine strata; it rests upon granite, and is covered with volcanic beds, so that the geological position bears no analogy to that of the Paris basin. The shells it contains are those chiefly of lymnites and the

planorbis; species which are found recent in our present lakes, and ponds. When I examined this limestone early in 1822, I found bones of mammalia, imbedded in it, presenting the same appearance as the bones in the gypsum at Montmartre. At that time I believe the occurrence of such bones was unknown to the geologists at Paris. The bones have since been ascertained to belong to similar species as those in the Paris basin; hence it is inferred, that the two formations were nearly cotemporaneous. The limestone under Mount Gergovia, near Clermont, which contained the remains of mammalia, was excavated for agricultural and other uses; it resembled the darker beds of soft English chalk, and was regularly stratified.

The extent and boundaries of the tertiary formations in England, are represented in the Map, Pl. 6, by the parts colored dark brown, within the lines *o-o-o-o;* but if the strata of the London basin and the Isle of Wight were once continuous, the tertiary formations have covered a great part of what is now the south-eastern division of England.

CHAPTER XVIII.

ON THE UPPER OR MORE RECENT TERTIARY STRATA.

The Methods for determining the relative Age of Formations explained, and their Value examined.—Evidence from Position.—Evidence from Organic Remains.—System of M. Deshayes founded on Fossil Shells.—Uncertainty attending the Evidence from Organic Remains.—Arbitrary Classifications of Naturalists.—Supposed Limits to the Transmutation of Species of Molluscous Animals examined.—System of M. Elie de Beaumont.—Geological Age of Palæotheria—of Mastodons—of Elephants.—Recent Tertiary Strata of the Basin of the Loire.—Of the sub-Apennine Ranges.—Of the Fresh-water Formations in the Apennine Valleys.—Remarkable intermixture of the Skeletons of Whales, Elephants, &c. at Castello Arquata explained by what has taken place in England.—Fresh-water Limestone of Œningen—Sandy Depositions of Norfolk and Suffolk called Crag.—Observations on the Tertiary Formations compared with the Secondary.

After the discovery of the true character of the tertiary strata of the Paris basin, and of England, it was for some time believed that the former was a complete representation of the whole tertiary formations in every country, and that the strata of the London basin, and of the Isle of Wight, represented a portion of the strata of the Paris basin. It is now, however, ascertained, that in the central and southern parts of France, and in many other countries, there are extensive tertiary formations, very different from those in the Paris basin.

These strata are, with much probability, believed to have been deposited in detached lakes or estuaries, at a subsequent period to that in which the Paris basin was laid dry.

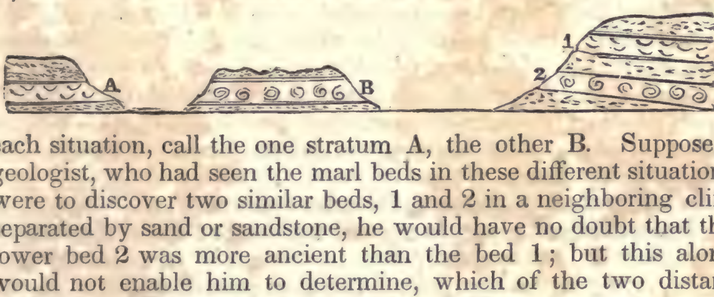
It also appears probable, that these newer tertiary strata are of different ages; and that some of them approach in their characters to the depositions at present forming on the shores of the ocean, or in the deltas of great rivers, or in fresh-water lakes.

The relative antiquity of these recent tertiary formations, is a subject of high geological interest, as it is connected with the history of the latest revolutions of the globe, and the catastrophes that have destroyed the ancient races of its inhabitants.

But how are the relative ages of the strata in different tertiary basins to be ascertained? The relative ages of two groups or formations of strata, or of two strata in distant parts of the same series, may be determined by two methods; one founded upon the evidence of position, the other upon that of organic remains. As the comparative value of these two kinds of evidence, and their relations to each other, has nowhere, that I know of, been briefly and clearly stated, for the benefit of the geological student I trust I shall be excused for attempting to give a simple and familiar explanation of each method. The evidence from the su-

perposition of strata, or what the French call *gisement*, is based upon a self-evident truth. In all stratified rocks that have been formed or deposited by water, the lowest stratum is the most ancient; or in other words, every stratum is older than the stratum that covers it; unless by some violent dislocation, the strata have been overturned, or removed from their original position. What is true with respect to two strata, may be applied to two series of strata, that occur under each other: thus, we are certain that the red sandstone and marl under the lias beds, are more ancient than the latter; and as both formations preserve the same character over a great extent, whenever we meet with them in other situations, where the superposition is not apparent, we may safely conclude, that the red sandstone is more ancient than the lias, and occurs under it.

We cannot, however, apply the same evidence to two groups of strata formed in detached lakes or basins. Let us suppose that two ancient lakes, situated at a considerable distance, had become dry in remote ages, and that a stratum of calcareous marl were found in what had been the ancient bed of each lake; it would be evidently impossible, from these data, to determine which stratum was the most recent, or whether their ages were coeval. Let us, for the better distinction of the stratum of calcareous marl in



each situation, call the one stratum A, the other B. Suppose a geologist, who had seen the marl beds in these different situations were to discover two similar beds, 1 and 2 in a neighboring cliff, separated by sand or sandstone, he would have no doubt that the lower bed 2 was more ancient than the bed 1; but this alone would not enable him to determine, which of the two distant strata, A and B, were the most ancient. If on attentively examining the beds 1, 2, in the cliff, he discovered one species of shells in the bed 1, and a different species in the bed 2, and afterwards found that the shells in the bed A were similar to those in the stratum No. 1 of the cliff, and that the shells in the bed B were similar to those in stratum 2, he would have strong presumptive evidence, that the bed B was more ancient than the bed A. This evidence from organic remains, or what is called Paleontology, becomes more satisfactory, in proportion to the number of instances in which it is supported by the evidence from position.

In the above example of the strata of calcareous marl in the two ancient lake beds, the evidence of their relative ages derives all its value from the original evidence of position afforded by the marl beds 1 and 2 in the cliff. The evidence from organic re-

mains alone, must ever be attended with uncertainty, unless originally confirmed by the evidence from superposition. Animals whose remains are deposited in distant basins, may be of different species; but this does not prove that they did not live at the same period, as we find in the present day different species inhabiting the ocean in different latitudes; difference of temperature in the waters of different lakes in the same latitude, might occasion a great change in the character of the inhabitants. The consideration, that the value of the evidence from organic remains, was originally derived from the evidence of position, and must ever remain more or less dependent upon it, appears to have escaped the attention of many geologists, exclusively attached to the study of zoological characters. Among our ingenious neighbors, the French, perhaps too ready to form generalizations from a limited number of facts, the value of the evidence to be derived from the study of fossil conchology is greatly overrated, when they would make it independent of position or *gisement*. Could the most scientific conchologist or naturalist have discovered from the organic remains in the Wealden beds, whether they were deposited before or after the green sand? Certainly not. He might have ascertained that they were fresh-water, and not marine beds; but this would not have assisted him in discovering their relative age. Fortunately we have here the evidence of superposition; for the green sand lies over the upper Wealden beds, and, therefore, is a later deposition. When the different periods of time shall be known, in which different species of animals first appeared in different latitudes, then, and not till then, can we predicate with certainty respecting the relative age of strata, from their organic remains alone.

I shall now proceed to state the rules attempted to be established for determining the relative ages of the tertiary strata by organic remains.

M. Deshayes considers that the relative ages of different groups of strata or formations, may be determined by their zoological characters alone; that is, by the species of shells they contain. He forms two grand divisions of stratified formations:

1. Those which contain no species of shells analogous to existing species.*

This division is stated to comprise all the secondary strata.

2. Strata which contain a greater or lesser number of species analogous to existing species.

The last division comprises all the tertiary formations. Again he subdivides this division into three groups, according to the greater or lesser proportion of species of shells that they each contain, analogous to living species.

---

* By *espèce analogue*, M. Deshayes means identical species.

In the more ancient group he places the tertiary formations of the Paris basin, the London basin, the Isle of Wight, and of a part of Belgium, a small part of the Gironde, and the tertiary strata of the Vicentin.

In the tertiary strata of this group, nearly fourteen hundred species of shells have been found, of which thirty eight species are analogous to existing species, or about three in every hundred. Only forty two of these species appear in the upper tertiary, and none of the fourteen hundred species found in this group, have any analogy with those found in the secondary strata, not even in the most recent or chalk formation.

The second or middle group comprises the marls of Touraine, and other parts of the Loire, a great part of the basin of the Gironde, of Dax, of Austria, Hungary, and Poland, and a small portion of the sub-Apennine hills, in the environs of Turin. Geologists and naturalists had before only admitted one group of tertiary strata in Austria and Italy.

Of nine hundred species of fossil shells found in this group, and compared by M. Deshayes, one hundred and sixty are analogous to living species, or eighteen in every hundred, and one hundred and thirty species have continued to live, during the formation of the upper or more recent group.

The upper group comprises the sub-Apennine hills, the tertiary strata of Sicily, those of the Morea, the small basin of Perpignan, and the small basins bordering the Mediterranean. In this group, M. Deshayes is inclined to place the Norfolk crag, at least until its characters shall be better known.

M. Deshayes has recognized seven hundred species in the upper group, of which the greater half are analogous to living species. Thirteen species alone, M. Deshayes observes, have yet been found common in all the three tertiary groups, and have resisted the destructive causes that have successively modified the organization of submarine animals. The living species, analogous to the fossil shells in the more ancient and middle groups, are chiefly inhabitants of tropical climates, whereas the greater number of species found in the most recent group, are analogous to those now living in European seas.

The results of M. Deshayes' researches, if fully confirmed, would establish the following rules for determining the relative ages of strata:

1. That in proportion to the greater number of fossil species in strata analogous to living species, such strata may be determined to be more recent.
2. That a great change in the organization of fossil species, and in the proportion of the number analogous to living species, ought to be considered sufficient to constitute different formations.

3. That different tertiary basins were not formed or filled contemporaneously.

Before admitting the conclusions of M. Deshayes, it will be right to pause and consider well how little we know of the inhabitants of the shells which are divided by conchologists into such a multitude of species, from a trifling difference of form. Molluscous animals, having no internal skeleton, appear to possess great power of adaptation; and, in some instances, it is proved, that they change the forms of their shells, when placed in different circumstances. It therefore seems to be travelling far beyond the bounds of sober experience, to establish such sweeping generalizations, on the evidence of shells alone. Where other concurrent evidence can be adduced, either from the organic remains of plants, or the higher classes of animals, the presence or absence of certain species of shells, may serve conjointly as distinctive characters of formations; we may farther admit, that the greater abundance of supposed species of shells, in any formation, analogous to existing species, implies that the conditions under which the strata were deposited, were analogous to the present condition of the globe, whether all the shells designated as different species were really so or not.*

Change of form, much greater than what exists in the coverings of many testaceous animals, said to be of different species, may be observed to take place in the same species of mammiferous animals in different countries. The sheep of Africa, of Asia, and of Europe, present great varieties of form; and even in Europe, the difference between one breed of sheep and another, in respect to form, size, or horns, is much greater than between the forms of many shells described as different species. Let us suppose the race of sheep to be entirely destroyed in some future revolution of the globe, and the skins and horns alone to be preserved in a fossil state, without any portion of the skeleton, or of the hoofs or teeth. The future geologist or naturalist would have as much reason to establish specific distinctions from the fossil skins, as the conchologist has to establish them from fossil shells. The external covering is all that can guide either of them; for of the animals themselves the conchologist knows nothing, absolutely nothing, that can serve for a specific character. The future dealer in fossils might establish forty species or more of the genus Ovis. Thus he would have his *Ovis maximus, O. medius, O. minimus, O. lanigerens, O. crinigerens, O. cornutus, O. bicornutus, O. quadricornutus, O. longicaudatus, O. pinguicaudatus; cum multis aliis.* Much ingenious and learned

---

* A classification and nomenclature of the tertiary formations, founded on the theory of Deshayes, has been introduced by some English geologist, which will be noticed in the Appendix.

speculation would doubtless be expended, to prove the epochs in which each species flourished, and to determine the geological ages of the horned and fat-tailed sheep.

Few persons ever made more experiments, for a long series of years, on the change of form and other qualities of animals, that might be permanently produced, than the late Mr. Robert Bakewell, of Dishley in Leicestershire. I have heard him say, that he scarcely knew any assignable limits beyond which these changes, both external and internal, might not be carried. I am fully convinced that the Author of nature has established laws for the preservation of distinct classes and orders of animals; but be it ever remembered, that these laws are not limited by the artificial classification of naturalists. The principle on which Mr. Bakewell proceeded, was this:—He first travelled over England, and part of the continent, to discover and select animals of the same species, possessing certain peculiarities of form, and other qualities which he was desirous to render permanent. By selecting two animals to breed from, which possessed the desired qualities in an eminent degree, and afterwards selecting from their offspring those in which these qualities were most conspicuous, and breeding again from them, the peculiarities were farther increased. By continuing the same selection through four or five generations, he obtained races that would transmit the same qualities permanently to succeeding generations.*

Naturalists class the sheep and the goat as two distinct genera of ruminating animals, but according to the most approved test of specific differences they are mere varieties of one species. The mixed breed is permanently prolific. Cuvier says of the sheep, "Ils meritent si peu d'être separés generiquement des chevres, qu'ils produisent avec elles des metis fecondes."—*Regne Animal*, tom. i, p. 477.

Some naturalists have maintained, that an additional vertebral bone was amply sufficient to establish a distinct species; but the number of vertebræ are not invariably the same even in man. In some of the negro tribes, an additional vertebral bone is not uncommon. To apply what has been said to fossil conchology:—The molluscous animals that inhabit and construct their shells,

---

* Mr. Bakewell, of Dishley, was in a considerable degree self-educated, but he possessed a strong original mind, which was enlightened by study and meditation: he was also a man of great moral worth, and was intimately acquainted with Dr. Priestley, Dr. Darwin, and other eminent philosophers who inhabited the central parts of England, towards the close of the last century. The late Countess of Oxford once asked the author of the present work, *whether he was related to the Mr. Bakewell who invented sheep?* He replied, that he was the same Leicestershire, or originally Derbyshire, family, and that Mr. Bakewell the *inventor* of sheep said, that "he felt satisfaction, not in having provided for the tables of the rich, but for the families of the laboring classes, to whom a pound of his fat mutton over a dish of potatoes, made a cheap and nutritious dinner."

have no internal skeleton, and must, therefore, be susceptible of greater change, and possess greater power of adaptation to circumstances, than vertebrated animals, in which the solid bones present obstacles to any essential departure from their original form.

Let us, however, imagine what is very possible: that a number of individuals of one species of bivalve or univalve shell, were driven, during a violent storm, into a distant part of the ocean, where the animals could no longer obtain their accustomed food, but were still able to support life, by aliment of a somewhat different kind. Let us suppose that the annoyances to which they had before been subject, from natural enemies or other causes, were changed for annoyances of another kind. Under these different circumstances, is it not probable that the animals themselves would undergo some change, and modify the construction of their shells in some degree, to render them better suited to the new conditions in which they were placed? Thus, in the course of a few generations, we should have a race which conchologists would call a distinct species.*

Where a series of tertiary strata of great depth is exposed to observation, as in the case of the sub-Apennine strata, we have the evidence of position, that the uppermost beds are the most recent; and if, in ascending from the lower to the upper part of the series, we find the proportion of the species increase, that are analogous to what now live in the Mediterranean, the evidence of position would support some of the conclusions of M. Deshayes. The evidence from position forms, however, the fundamental basis of our conclusions respecting the relative age of the secondary and tertiary formations, and we can only proceed safely when we have the aid of this evidence.

M. Elie de Beaumont proposes a division of the tertiary strata into three groups, according to the organic remains of large mammiferous animals which they contain. He supposes that each of these groups indicates a period of tranquillity intermediate between two periods of change and convulsion, and that each generation of animals was destroyed by a different convulsion.

* What was above stated hypothetically in the 4th edition of this work, may now be asserted as ascertained facts. Dr. Harlan, a distinguished American naturalist, informed the author, that testaceous molusca removed from one river to another in America were observed in time to change the form of their shells. Mr. Gray, in the Phil. Trans. 1833, states, that great varieties of form are produced in shells of the same species, by a removal from calm to agitated water. The *Buccinum undatum*, and the *B. striatum*, differ only by the one having lived in calm water, and the other in a rough sea. He enumerates several shells of the Murex, regarded by conchologists as distinct species, from their great difference of form, which in fact belong to animals of one and the same species, living under different conditions. It may be farther added, that difference of age sometimes occasions great difference of form in shells. Nothing can be more uncertain and fallacious than the establishment of species from the shell, without some knowledge of the organization of its inhabitant. We might with almost equal certainty describe the character of nations from the form of their clothes.

His first period extends to the marls above the gypsum, in the Paris basin. The second to the Fontainebleau sandstone, the upper fresh-water formation, the calcareous beds at the mouth of the Rhine, and the molasse of Switzerland. The third period extends to the diluvium (*terrain de transport*) of Bresse, to the beds of Œningen, the sandstone of Aix, the upper marine formation of Montpellier, and the ranges of sub-Apennine hills in Italy, to the tertiary beds of Sicily, and to the Crag of Suffolk.

The first or lowest group is characterized by the remains of palæotheria; the second, by those of mastodons; and the third, by the remains of elephants. It is admitted, however, that in marine tertiary depositions, these periods seem to pass insensibly into each other. In the marls of the Loire, and the calcareous beds of Montpellier, the bones of the palæotherium are found mixed with bones of the mastodon and hippopotamus; and in the Plaisantin, the bones of the elephant are added to the above. Without admitting at present, that the division of M. E. de Beaumont is supported by sufficient evidence, (and the exceptions stated prove that it is not,) yet we may still allow, that there is a considerable degree of probability, that each of the three groups of animals flourished most at the different epochs he has stated, but not exclusively of other genera. In England, we have only a few traces of animals of the palæotherian age; these occur in the fresh-water formation at Binstead, in the Isle of Wight: and of the second group we have only two doubtful instances; they occur in the Crag, in which two teeth of the mastodon have been found. In the third, or elephantine group, we have numerous instances; for teeth and bones of elephants have been found in the Crag of Norfolk, and in clay, marl, or gravel, in almost every county in England. The instances cited above, in the two lower groups, are too few to support any hypothesis; but it is only fair to admit, that, conjointly with the elephants in the third group, they are conformable to the divisions of M. E. de Beaumont.

In a work like the present, it would not be possible or desirable to follow the French and German geologists, in their descriptions of the different basins that contain the upper tertiary or quaternary strata, supposed to be superior to any of the tertiary beds in the Paris basin, or in England; but the most remarkable of these formations may be noticed:—"The Faluns, or marls of Touraine and the Loire, constitute an extensive formation of marl beds, which are now admitted to be of later date than the most recent of the fresh-water beds in the Paris basin. From the soft quality of the marl, it might hence be inferred, that the beds had been disturbed or changed by inundations, or might be classed with diluvial beds; but they are regular depositions, formed during an epoch of tranquillity, and subjected to laws, of which

the action is continued on the present shores. The great mass of fossil shells which these beds contain, differ from those of the Paris basin: in nearly four hundred species, there are only about twenty identical with the Paris fossils. The terrestrial and river shells are in the same state of mineralization as the marine shells. The bones of the mastodon, rhinoceros, and hippopotamus, are in the same state of preservation as those of whales, and other cetaceous animals, with which they are intermixed. They are coated with marine polypi and serpulæ, which proves that they were long covered by a tranquil and stationary sea. These Faluns are distinct from the tertiary beds of the Seine, and more recent than any of them; but they are themselves the lowest term of a new system, more important, more extensive, than the formations of the Paris or London basins, and which has been continued to the present epoch, during all the numerous upheavings of the ground, the changes in the relative level of seas and continents, and the successive modifications of organic beings."—*Bulletin de la Société Géologique de France*, 1831–32, tom. ii.

It is stated that the lowest bed of the Faluns, rests upon a bed analogous to the upper part of the Paris basin, which is supposed to have extended so far. If this were clearly made out, we should have the evidence of position, as well as of organic remains, to determine the relative age of the Faluns of the Loire, which is supposed to be the age of mastodons. In opposition to this, I have part of the tooth of an elephant, which, in the handwriting of Faujas St. Fond, is said to have been found at Montmartre, and is evidently from the marl beds. Here, then, we have remains of an animal of the most recent tertiary age, occurring in a formation more ancient than the age of mastodons. Such instances should lead us to receive the evidence from animal remains alone, with much caution. Indeed, there is good reason to believe, that in North America, the age of mastodons was continued to nearly the present epoch, if the animal be not still living, in some of the unexplored recesses of that vast continent.

The range of mountains in Italy, called the Apennines, that rise, in some parts to the height of from six to eight thousand feet, and extend north and south from the borders of Piedmont to Calabria, are accompanied, both on the Adriatic and Mediterranean flanks, by ranges of lower hills, which have, from their position, received the name of sub-Apennine hills. The sub-Apennine hills rise to the height of from one to two thousand feet; they are composed of nearly horizontal tertiary beds of marl, sand, clay, and calcareous tufa, and abound in marine shells, many of which are identical with existing species in the Mediterranean sea, or with other existing species of tropical climates.

It is observed that the upper beds contain the greatest proportion of species, similar to what exist in the neighboring seas. The sub-Apennine beds rest unconformably upon the inclined beds of the Apennine range. It has been ascertained, by dredging the bed of the Adriatic sea, that there are beds now forming at the bottom, more than a thousand feet high, which closely resemble beds in the sub-Apennine hills. These sub-Apennine beds have once formed the bottom of an ancient sea, and have been raised to their present elevation by subterranean action. The occurrence of numerous volcanic vents, in the whole of that part of Italy, can leave little doubt respecting the agent by which this elevation has been effected.

Whether any portion of the sub-Apennine strata belong to the same epoch as the upper strata in the Paris basin, may be doubtful; but we may safely infer, both from their organic remains and position, that the superior sub-Apennine beds, belong to a far more recent epoch, than that in which the tertiary strata round Paris and London were deposited. Mr. Lyell, who has recently examined this interesting range of tertiary hills, and has extended his researches into Sicily, says, "there were many places in which the extinct species had nearly disappeared; and that amid vast accumulations of marine shells, entering into the composition of mountains of no inconsiderable altitude, nearly all were specifically identical with those now inhabiting the adjoining sea." According to the principles of M. Deshayes, these Sicilian beds must be more recent than the sub-Apennine.

One thousand species of shells have been collected by Signor Guidotto from the sub-Apennine beds; and if the rules laid down by M. Deshayes, respecting this formation, can be relied upon, the greater number of the species of shells belong to existing species; of these the *greater proportion* belong not only to existing species, but to species inhabiting the neighboring sea. In Sicily, however, we approach much nearer to the present state of things, as *nearly all* the shells in the tertiary strata are identical with living species, and probably existed under similar conditions of temperature, &c. to what these latitudes are now subjected. Approaching the northern termination of the sub-Apennine range at Sienna, Parma, and Asti, (according to Mr. Lyell,) the proportion of species identifiable with those now living in the Mediterranean is still considerable; but the proportion no longer predominates (as in the south of Italy) over the unknown species.

As these sub-Apennine hills, which cover the flanks of the Apennine range on each side, were formed under the sea, they must have been elevated together with the Apennine range subsequently to their deposition. Before this period, the Apennines were consequently much lower, and formed a narrow mountain-

ous peninsula, extending into the Mediterranean. Their sides were probably clothed with forests, and afforded food and shelter to the elephants and other large mammalia, that have left their bones so abundantly in some of the present valleys, particularly in the vale of Arno. These valleys, it is supposed, were once the beds of ancient fresh-water lakes, in which depositions were forming at the same time as the marine depositions were taking place, which constitute the beds of the sub-Apennine range. By the observations of M. Bertrand Geslin, published in the *Journal de Géologie*, t. iii, it would appear, that between the source of the Arno and Florence three distinct basins can be traced. The beds of these basins are composed of argillaceous blue marl of considerable thickness, containing fossils in the upper part of the marl. Above this are beds of sand, containing numerous bones of large mammalia. These sands are covered by beds of rolled siliceous pebbles, intermixed with sand, above which there is a bed of yellow argillaceous sand. The pebbles appear to have been derived from the mountainous range on the north. Neither remains of marine shells nor lignites occur in these depositions. The animal remains in the upper valley of the Arno are those of the elephant, the large hippopotamus, the rhinoceros, the tapir, the deer, the horse, and the ox. There are also bones of carnivorous animals belonging to the hyena, the bear, the fox, and some species allied to the tiger. From the character of the animal remains we may infer, that these fresh-water depositions are of a comparatively recent date; they were probably coeval with the uppermost marine beds in the sub-Apennine hills. The beds, both in the sub-Apennine hills and in the valleys of the Apennines, consist principally of marl, sand, and loosely adhering materials: hence they are exposed to rapid degradation. On the northeast side of the Apennine range, in the district of Placenza, there is a marine deposition deserving particular notice, from the extraordinary mixture of animal remains which have been found in it, and are at present preserved in the Museum at Milan.

A friend of the author, S. Banfill, Esq. of Exeter, who visited the Museum in 1832, obtained from the director of that institution, an account of the principal organic remains from this deposition, with a brief notice of the locality, of which the following is a translation:—

"Organic remains from near Castello Arquata, in the neighborhood of the ancient Velleja, in the district of Placenza.

"A pretty extensive collection of shells.

"A small whale, entire.

"A portion of another whale, of a larger species.

"The entire skeleton of an elephant, united together.

"The head of a rhinoceros, with some bones.

"Two skeletons of dolphins.

"They were all found in a confined space, in the midst of marine mud, deposited in a tranquil sea, at the present height of thirteen hundred feet." The director adds, "This singular geological combination, comprehending organic vestiges of every latitude, resembles that recently discovered in New Siberia, at Behring's Straits. Many eminent writers have spoken of it; among others, the brothers Bondi were some of the first who noticed it; and Signor Corlesi, a landed proprieter at Castello Arquata, and author of 'Geological Essays on the States of Parma;' also Signor Brochi, in his *Sub-Apennine Fossil Conchology.*"

The occurrence of the remains of large terrestrial and of marine mammalia in the same deposition, may admit of an easy explanation, by observing what has taken place in some parts of England. On the Sussex coast there was, at no remote period of history, an estuary extending inland from Newhaven to near Lewes. This estuary is now filled up, and forms a level meadow, through which the river winds its way to the sea. It is not difficult to explain how the filling up of the estuary was effected: the immense mass of loose pebbles or shingles which lie upon the Sussex coast, change their position during violent storms, and are accumulated in new situations. A drift of pebbles, forming a bank or bar near the mouth of the estuary would prevent the sudden return of the sea after each tide, and retain the water until it had deposited the mud and sand which it contained. Thus the estuary would gradually become shallower, and its dimensions would contract from year to year. The waters of the river and rivulets, which flowed into the estuary, would also contribute their depositions of fresh-water mud.

By the joint operation of these causes, the estuary would be first converted into a marsh; and when the drainage was more complete, this marsh was converted into a plain or meadow. By sinking beneath the soil, the various depositions of silt, sand, and vegetable matter, prove the means by which the estuary was filled. At a considerable depth, large vertebræ of a whale were discovered, and are now in the museum of Dr. Mantell. Instances of whales entering estuaries at high tides, and being unable to return at low water, are of not very unfrequent occurrence on the coast of Great Britain. Let us suppose the sides of the hills bounding the estuary near Newhaven, to have afforded herbage for deer and oxen; their bodies or bones might be washed down into the estuary, and thus we should have all the conditions required for the intermixture of the large bones of terrestrial and marine animals. Let us farther suppose, that subterranean fire, like that which exists under various parts of Italy, should upheave the chalk hills of the South Downs, and all the surrounding country, to the height of two thousand feet above the present level: the bed of the Newhaven estuary would then

resemble, in all its essential characters, the deposition at Castello Arquata, in Italy.

The fresh-water strata at Œningen, near Constance, are perhaps the most recent of all that have been described as tertiary formations. Quarries have for many years been worked in these strata, and they have been long celebrated for the great variety of organic remains which they contain, consisting of quadrupeds, birds, a vast number of fishes, reptiles, insects, and innumerable plants. These quarries were, for a considerable time, supposed to contain human skeletons: it has been ascertained by Cuvier, that the bones belonged to the aquatic salamander, an animal nearly resembling the lizard in form. The body is about four feet in length, and it had beside a long tail. One of these skeletons is in the British museum. The strata are chiefly indurated calcareous marl, and fresh-water limestone or marlstone. Mr. Murchison, who visited the quarries at Œningen, and brought from thence the entire skeleton of a fossil fox, has given a brief, but very clear description of this formation:

"The Rhine, in its course from Constance to Schaffhausen, flows for many miles in a depression of the molasse, (or sandstone,) which, being cut through transversely, is exposed in hills on both banks, at heights varying from seven to nine hundred feet. These hills, consisting of micaceous sandstone and conglomerate, form the western prolongation of that great range of tertiary deposits, which extends along the flanks of the Austrian and Bavarian Alps, and has been described by Professor Sedgwick and myself. The marls and limestone of Œningen are recumbent on the molasse, and they are seen in various patches on the sides of the hills, and are worked in two quarries, at different elevations above the Rhine. The lowest is about two hundred feet above the level of the Rhine; the highest is about six hundred feet above its level. The marl beds in both, rest on molasse, which, forming the bottom of the basin, is exposed beneath the lower quarries in the denudation of the Rhine, and rises behind them into the hills of Schienen. It would, therefore, appear, that the valley in which the Rhine now flows, was, at a remote period, deeply excavated in the molasse, and that subsequently a lake was formed in one of the broader parts of the valley, in which marls and limestones were deposited. The nature of the organic remains, and their deposition in successive layers, not only prove the long period of time which must have elapsed during their accumulation, but also demonstrate the lacustrine origin of the deposit."

Mr. Murchison has annexed some judicious observations on the relative geological age of the tertiary limestone of Œningen. "From the intermixture of species undistinguishable from those now existing, with others decidedly extinct, this deposit may be considered as an important link in the history of the earth's struc-

ture; indicating an intimate connection between the ancient state of nature, and that which now prevails.

"The deposit differs essentially in its organic remains from any other fresh-water formation either in France or in the adjacent regions of Germany: from its superposition over tertiary sandstone, (molasse,) this formation must be regarded as one of the most recent. Yet recent as must have been the (geological) epoch of this formation, the basin in which it was deposited has subsequently been re-excavated to a considerable depth: the proof of which is, that horizontal beds still present escarpments several hundred feet above the Rhine, without any barrier between them and that river."

As no bones of elephants or mastodons have been discovered in the strata of Œningen, and as the plants and animals for the most part resemble existing species, it is reasonable to believe, that the mean temperature of this part of the globe had considerably decreased, and that the country round Œningen could no longer support the plants and animals of tropical climates.

The strata of Œningen may be regarded as posterior to many of the beds or accumulations of clay, sand, and gravel, in England and other countries, and contain the remains of elephants, hippopotami, and other inhabitants of warm regions.

Crag.—In the county of Norfolk, beds of sand and gravel are provincially called Crag: such beds cover a considerable extent of country from the coast near Cromer on the north, to the southern boundary of the county, and thence are continued through Suffolk, and into the confines of Essex. These beds chiefly rest upon chalk; but in Suffolk, they often cover London clay. Thin irregular beds of sand, almost entirely filled with marine shells, are found in some parts of the Crag; and since the attention of geologists has been particularly directed to them, they have been distinguished from the other beds of sand, gravel, and clay, and the term Crag, is now exclusively given to these shelly deposits. Having visited part of the Crag district in Norfolk since the publication of the edition of 1833, I confess that I was somewhat surprised and disappointed at the importance that had been given to these limited depositions of strata containing shells. At Brammerton, near Norwich, the Crag strata are very well displayed; they consist as under, in an ascending series:

Feet.	
15	of sand and clay with shells, resting on chalk.
4	Coarse white sand.
15	Yellow and red sand.
1½	Pebbles and shells.
1½	White sand and shells.
1½	Ferruginous sand.
4	Loamy earth.
2	Vegetable mold.

For the measurement of the different beds I am indebted to Mr. S. Woodward, author of *An Outline of the Geology of Norfolk*, and of various papers on the natural history and antiquities of that county. At Thorp, and other localities which I visited, the thickness and succession of the beds vary somewhat from those of Brammerton. The greatest altitude of these beds, above the sea is supposed to be about one hundred feet. On the coast at Cromer, the Crag strata are found at the bottom of the cliffs, nearly on a level with the sea, and a little below the low water mark: the substratum of chalk on which the Crag rests, may be traced for some miles. The cliffs, composed of sand, clay, and gravel, above the Crag, are in some parts four hundred feet in thickness.

As the shells in the Crag, both bivalve and univalve, are marine, the difference of level at which the beds of Crag are found at Cromer and inland, proves that a considerable elevation of the surface has taken place in some parts since their deposition. It is generally agreed, that a large proportion of the shells found in the Crag, belong to species not at present existing in the neighboring ocean. Many of the more delicate shells have been broken, but the stronger shells, particularly those of the Murex, are in high preservation. No shells of the nautilus or any other large chambered cephalopod, have hitherto been found in the crag.* The general characters of the country containing the Crag are ably given by Mr. Taylor:—"A district, bordering a hundred miles upon our eastern coast, is occupied by an ancient marine deposit, continually changing its aspect, yet constant in its peculiar characters, and always to be understood by unerring data: now appearing as a ferruginous sandstone, then a compact clay, and again considerably indurated; sometimes blended in a mass of extinct zoophytes, sponges, and alcyonites, forming a soft rock: oftener an irregularly accumulated mass of decomposed and broken littoral shells, loosely imbedded in sand, like an ordinary sea beach, yet accompanied with the remains of unknown animals: sometimes forming the substratum of a considerable area; or overwhelmed beneath the debris of older strata, only detected at intervals:—at one point exhibiting groups of shell fish allied to those of the neighboring sea; and at another, composed of numerous genera, which are neither to be recognized living in any part of our globe, nor assimilating to the fossil shells of other formations."—*Phil. Mag.* April, 1827.

Mr. Taylor, in his account of the Norfolk crag, appears to associate with it the beds which Mr. Woodward describes as dilu-

---

* Numerous minute shells, allied to the nummulite, are found in the Crag, but these, according to Dr. Milne Edwards, did not belong to cephalopods, as hitherto believed, but to species of polypi. See Preliminary Observations in the present volume.

vium; hence he gives a greater extent to the crag formation than Mr. Woodward.

Mr. Edward Charlsworth described, in the Edin. Phil. Mag. August, 1835, a lower bed of crag in Suffolk, beneath the common, or, what he calls, the red crag. This bed is composed of calcareous sand, containing shells, corals, and sponges, well preserved: the sand itself appears to be chiefly derived from decomposed corals. To this deposition he gives the name of Coralline Crag. In the Proceedings of the Geological Society, February, 1837, there is an abstract of a paper by the Rev. W. B. Clarke, describing the geological structure, &c. of Suffolk, and its relations with Norfolk and Essex. Mr. Clarke believes, "that the true rationale of the crag is to be found in the hypothesis of sand banks inhabited by testacea, and situated in a tidal way, exposed to violent fluctuations of the sea, as well as subject to drifts of extraneous matter from land waters." This opinion of Mr. Clarke's appears to have just grounds for its support, particularly when taken in connexion with the vast accumulation of mammalian remains, found in or near the crag. These remains, particularly those of the elephant, are so abundant, that the district might be called the land of elephants. They are generally well preserved, and hence it may be inferred, that they have not been drifted from a distant country. The bodies were probably carried by some powerful river into the sea, and buried in sand or clay. After high tides these remains are laid bare, and washed upon the shore, and are found along the coast for several miles. An entire head of a large elephant was found near Cromer a few months before I was there, in 1835. The tusks were rising above the sand, but were broken by the boys who discovered them; the jaws and grinders escaped mutilation. It is about twenty years since the mammalian remains attracted particular attention. On removing a bed of clay to form the jetty at Cromer several large teeth and bones were discovered and collected. On the Hasboro' sand banks near the coast, the remains of elephants are abundant; they are constantly dredged up by the fishermen. It is supposed by Mr. Woodward, that the teeth collected from these banks alone, in a few years, must have belonged to five hundred elephants. The bones most commonly found are the pelvis and femur. The teeth and tusks of the hippopotamus and rhinoceros are also occasionally found. Similar mammalian remains occur in or near the crag beds, in various parts of the county of Norfolk. The blue clay, under which the mammalian remains chiefly occur at Cromer, is covered by thick beds of sand and gravel, that form the cliff; but as these cliffs are annually and rapidly falling, the lower beds become exposed to the action of the tides, and the bones and teeth are washed out, and spread upon the sand. In *Loudon's*

Magazine of Natural History, January, 1836, I have given a more detailed account of the large mammalian remains found in the crag, and on the coast of Norfolk.

The animals whose remains are buried in or over the crag of Norfolk, certainly were not more ancient than the crag itself. This fact entirely invalidates the conclusion respecting the high comparative antiquity of the Suffolk coralline crag, founded on the temperature required for the growth of coral; for the climate suited to the elephant and hippopotamus was, assuredly, sufficiently warm, to admit coralline polypi to flourish in sheltered situations, as they do at present in the Mediterranean sea. The beds of Norfolk crag, were probably more exposed to the violent fluctuations of the tides, than the coralline beds.

The crag offers a striking instance of the influence of mere names over the judgment, in science as well as in the common concerns of life. Had the beds denominated crag, been at first called what they really are, beds of shelly sand and pebbles, and had it been farther stated, that the shells were marine, and some of them were supposed to differ from the shells in the neighboring sea, the information so given would have excited little curiosity. The unknown and mysterious name of crag, and the vast extent to which the said crag was believed to be spread over the counties of Norfolk and Suffolk, gave it the character of a principal geological formation. The geological importance of the crag, may in some degree be estimated by the section of it at Brammerton, where it appears in its greatest force. The total thickness of the three shelly beds to which the term crag is now restricted, is not more than eighteen feet: and even if we class as crag all the beds between the chalk and the vegetable mold, the thickness will be about forty feet; nor are these beds regular or continuous to any great distance. It is highly probable that the loose sand banks which formed the crag beds, have been in some situations drifted over the coralline crag; the evidence of superposition in beds of sand or gravel, affords no certain proof of difference of age. The importance of the shelly crag has been much overrated, while the mammalian remains, which are of far higher value, have hitherto received little attention from geologists. The shells in the crag are not "vocal;" they tell us nothing—absolutely nothing—respecting the former condition of the globe; they convey no information, except that they differ somewhat in form from the shells in the German ocean; but the skeletons of hippopotami and of many hundred elephants, declare, in a language not be mistaken, that the earth in these latitudes, possessed a very high temperature, at a late period of the tertiary epoch.

Observations on the Tertiary Strata.—In passing from a secondary district to one denominated primary, the traveller will generally observe a remarkable difference in the nature of the soil and the physical features of the country, which may lead him to infer, that a great geological change had taken place; but in passing from the secondary to the tertiary formations, there is seldom any striking variation in the scenery or external characters to excite particular notice.

In the organic remains of the tertiary strata, however, the geologist may discover proofs of the most extraordinary changes that have, perhaps, ever taken place on the surface of the globe. The era of a new creation appears to have commenced, both in the animal and vegetable kingdoms. The highest class of animals, the vertebrated mammalia, of which scarcely a vestige can be found in the secondary strata, have left abundant remains in the tertiary formations, belonging to various orders and genera, some of which are continued to the present day. In the vegetable remains also, we trace a similar change, from families of the lowest classes, to perfect dicotyledonous plants, allied to our present forest trees. "Thus (as M. A. Brongniart well observes) in the vegetable as well as the animal kingdom, there has been a gradual advancement to perfection in the organization of beings which have successively lived upon the globe, from those which first appeared upon its surface to those by which it is now inhabited."

That a great change must also have taken place in the condition of the globe, previously to the creation of terrestrial mammalia, will, I think, on reflection, appear evident. The secondary strata were chiefly deposited under the sea, and it is highly probable that they were elevated above its surface, and formed a considerable portion of the present continents in the northern hemisphere, before the tertiary epoch commenced. Extensive tracts of dry lands, with rivers and fresh-water lakes, and with a covering of soil, would be required for the new vegetable and animal creations. It is farther probable, that by the emergence of the land, a considerable change took place both in the atmosphere and the climate, and that this change was favorable to the support and well being of terrestrial mammalia. M. A. Brongniart, in his "*Prodrome des Végétaux Fossiles,*" advances an opinion, that in the earliest geological epochs, the atmosphere contained a great excess of carbonic acid, which, combined with a high and moist temperature, promoted the rapid growth of gigantic ferns, lycopodia, and other plants, that composed the vegetation of the ancient world. By the absorption of the carbonic acid, the atmosphere became gradually more suited for the respiration of animals. The plants by which carbon was absorbed and solidified, furnished, as they decayed, the substance of which coal is formed. This conjecture is extremely ingenious, and well deserving the consideration of the geologist.

CHANGES

OF THE

SURFACE OF THE GLOBE

EFFECTED BY

INTERNAL AND EXTERNAL CAUSES.

VALLEY OF SIXT, IN SAVOY.

The preceding Chapters describe the composition, arrangement, and succession of the great mineral masses that form the solid covering of the globe. The more important phenomena they present, are particularly noticed, with a view to excite the attention and direct the researches of the geological student. The following chapters chiefly relate to changes which the solid covering of the globe has in many parts undergone by the operation of internal and external causes. The internal causes are removed from immediate observation, and can only be traced by their effects; they appear to be terrestrial heat, electricity, and chemical affinity. The external causes are solar radiation, variation of temperature, atmospheric agency, the force of descending waters and currents, and the action of the tides; to which may be added the deposition of calcareous beds in the ocean, by testaceous animals, and zoophytes.

CHAPTER XIX.

OF EARTHQUAKES AND VOLCANOES.

Phenomena that generally precede the Shocks of violent Earthquakes.—Extent to which Waters in Lakes and Springs have been agitated during Earthquakes.—Extent to which Earthquakes have been felt on Land.—Connection between Earthquakes and Volcanoes.—Frequency of Earthquakes at particular Periods and in certain Countries.—Enormous destructive Waves produced by Earthquakes; their effects on the coast of Chili in 1835.—Electrical Agency.—Phenomena presented by Volcanic Eruptions on Land.—Remarkable Eruption of Sumbawa in 1815.—Long Periods of Repose in some Volcanoes.—Volcano of Popocatapetl in Mexico.—Submarine Volcanoes in various Parts of the Globe.—Volcanic Eruptions of Water and Mud.—Destruction and Extinction of Volcanoes.—Groups of Volcanic Islands.—Ancient extinct Volcanoes.—Extinct Volcanoes of the South of France, Puy de Pariou, Puy de Dome, and Puy de Chopine.—Volcanic Domes, remarkable one in the Island of Java.—Extinct Volcanoes near the Rhine, and in Asia.—Craters of Eruption, Theory of, by Von Buch.—Structure of Mont Somma and Monte Nuovo, confirmative of this Theory.—Observations on Volcanic Fire.—Pseudo Volcanoes and Volcanic Rocks and Products.

Accustomed to view the hills in our own country in a state of profound repose, presenting the same unvaried outline in each succeeding year, we can scarcely conceive the possibility of a whole district being covered with new mountains and another soil, in the space of a single night; yet such changes have been produced, by the united agency of earthquakes and volcanoes, within the limits of authentic history. For a particular description of recent volcanic eruptions, and the changes they have produced on the surrounding countries, I must refer the reader to the works of Spallanzani, Dolomieu, Sir William Hamilton, and M. Humboldt, and to the recent account of the Island of Java, by Lieutenant-Governor Raffles.

In the present chapter I propose, 1st, to describe those phenomena that indicate the connection between earthquakes and volcanoes, and between the volcanoes in distant countries; 2dly, to take a view of the most remarkable recent volcanic eruptions, and of the remains of ancient volcanoes, that prove the extensive action of internal heat on the crust of the globe; and, 3dly, to give a concise account of volcanic rocks and products.

Earthquakes and volcanoes may be considered as different effects produced by the agency of internal heat. They frequently accompany each other, and in all instances that have been observed, the first eruption of a volcano is preceded by an earthquake of greater or less extent. Volcanoes do not make their appearance in every country where the shock of an earthquake is felt; but earthquakes are more frequent in volcanic districts

than in any other. Earthquakes are almost always preceded by an uncommon agitation of the waters of the ocean and of lakes. Springs send forth torrents of mud, accompanied with a disagreeable stench. The air is generally calm, but the cattle discover much alarm, and seem to be instinctively aware of approaching calamity. A deep rumbling noise, like that of carriages over a rough pavement—a rushing sound like wind—or a tremendous explosion like the discharge of artillery, immediately precede the shock, which suddenly heaves the ground upwards, or tosses it from side to side, with violent and successive vibrations. The shock seldom lasts longer than a minute; but it is frequently succeeded by others of greater or less violence, which continue to agitate the surface of the earth for a considerable time. During these shocks, large chasms and openings are made in the ground, through which smoke and flames are seen to issue: these sometimes break out, where no chasms can be perceived. More frequently, stones, or torrents of water, are ejected from these openings. In violent earthquakes, the chasms are so extensive, that large cities have in a moment sunk down and forever disappeared, leaving a lake of water in the place. Such was the fate of Euphemia, in Calabria, in 1638, as described by Kircher, who was approaching the place, when the agitation of the ocean obliged him to land at Lopizicum. "Here," says he, "scenes of ruin every where appeared around me: but my attention was quickly turned from more remote to contiguous danger, by a deep rumbling sound, which every moment grew louder. The place where we stood, shook most dreadfully. After some time, the violent paroxysm ceasing, I stood up, and turning my eyes to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen, where the city once stood."

The extent to which earthquakes produce sensible effects on the waters of springs and lakes in distant parts of the world, is truly remarkable. During the earthquake of Lisbon, in 1755, almost all the springs and lakes in Britain, and in every part of Europe, were violently agitated, many of them throwing up mud and sand, and emitting a fetid odor. On the morning of the earthquake, the hot springs at Toplitz, in Bohemia, suddenly ceased to flow for a minute, and then burst forth with prodigious violence, throwing up turbid water, the temperature of which was higher than before: it is said to have continued so ever since. The hot wells at Bristol were colored red, and rendered unfit for use for some months afterwards. Even the distant waters of Lake Ontario,* in North America, were violently agitated at the

* It has been observed, during many earthquakes in the Eastern States, that the subterranean noise and motion appeared to commence from the Lakes, and proceed towards the Atlantic Ocean, in a direction from the northwest.

time. These phenomena offer proofs of subterranean communications under a large portion of the globe; they also indicate, that a great quantity of gas or elastic vapor was suddenly generated and endeavoring to escape. From the fetid odor perceived in some situations, it may be inferred, that this gas is hydrogen or sulphuretted hydrogen. In other instances it may be steam, which, condensing again, would produce a vacuum, and occasion the external air to press downwards; this has been observed in mines, immediately after the shock of an earthquake.

The space over which the vibration of the dry ground is felt, is very great, but generally wider in one direction than another; and where a succession of earthquakes has taken place in the same district, it is observed, that the noise and shock approach from the same quarter. It has been before mentioned, that earthquakes are most frequent in volcanic districts; but the shocks are not the most violent in the immediate vicinity of volcanoes. On the contrary, they are stronger in the more distant part of a volcanic country. The ground is agitated with greater force, as the surface has a smaller number of apertures, communicating with the interior. "At Naples and Messina, and at the foot of Cotopaxi and Tungurahua, earthquakes are only dreaded when vapors and flames do not issue from the craters."—*Humboldt.*

The connection of earthquakes with volcanoes was noticed by ancient writers, and the latter were properly regarded as the openings, through which the inclosed vapor and ignited matter, that occasion earthquakes, found a passage. Strabo, in his Geography, states, that, "the town of Rhegium, situated on the Italian side of the Straits of Messina, was so called, according to Æschylus, from the circumstance, that the island of Sicily was rent off from the continent by earthquakes. Proofs of this arise out of the phenomena attending Ætna, and other parts of Sicily, the Lipari Islands, and even the opposite continent. Now, indeed, when craters are opened, through which fire and ignited matter and water are poured out; it is said that the land near the Straits is seldom shaken by earthquakes: but formerly, when all the passages to the surface were obstructed, the fire and vapor confined in the earth occasioned frequent earthquakes, and the land, being rent, admitted the ocean. At the same time, Prochyta, and an adjacent island, were also torn off from the continent, while other islands rose from the ocean, as frequently happens at this day."—(Strabo flourished in the reign of Augustus.)

It is highly probable, that every extensive earthquake is followed by a volcanic eruption more or less remote, unless (as not unfrequently happens) the elastic vapor immediately escapes from fissures made at the time, in the countries that are the most violently convulsed. An earthquake was strongly felt in Geneva when I was there, February 19, 1822, and did considerable dam-

age in several towns and villages in Savoy and France. A few weeks afterwards, I travelled from Geneva to Lyons, and from thence to the ancient volcanoes near Clermont. In the course of my route, I made frequent inquiries respecting the effects of the earthquake: it appeared to have been most strongly felt along the valley of the Rhone, and the shock was not less severe in the volcanic district of Auvergne; its direction was from the south-east: and on that and the following days, there were several eruptions from Vesuvius.

The frequency of earthquakes at particular periods is well deserving notice. In the fourth and fifth centuries, some of the most civilized parts of the world were almost desolated by these awful visitations. Thrace, Asia Minor, and Syria, according to contemporary historians, suffered most severely: the earth was agitated continually for long periods, and flames were seen to burst from the earth over a vast extent of surface. On the 26th of January, A. D. 447, subterranean thunders were heard from the Black to the Red Sea, and the earth was convulsed, without intermission, for the space of six months; in many places, the air seemed to be on fire; towns, and large tracts of ground, were swallowed up in Phrygia. On the 20th of May, A. D. 520, the city of Antioch was overturned by a dreadful earthquake, and two hundred and fifty thousand of its inhabitants are said to have been crushed in the ruins. A raging fire covered the ground on which the city was built, and the district around; spreading over an extent of forty two miles in diameter, and a surface of fourteen hundred square miles.

About the middle of the last century, after the earthquake at Lisbon, Europe, Africa, and America were for some time repeatedly agitated by subterranean explosions; as may be seen by referring to the journals of that time. Ætna, which had been in a state of profound repose for eighty years, broke out with great activity; and, according to Humboldt, some of the most tremendous earthquakes and volcanic eruptions ever recorded in history were witnessed in Mexico. In the night of the 19th of September, 1759, a vast volcano broke out in a lofty cultivated plain; a tract of ground more than twelve miles in extent, rose up like a bladder to the height of five hundred and twenty-four feet, and six new mountains were formed, higher than the Malvern Hills, in Worcestershire. More recently (in 1812) the tremendous earthquakes in Caraccas were followed by an eruption in the Island of St. Vincent, from a volcano, that had not been burning since the year 1718; and violent oscillations of the ground were felt, both in the islands and on the coasts of America. It may be inferred from these circumstances, that the cause of earthquakes and volcanic eruptions is seated deep below the surface of the earth; in confirmation of which, it will only be

necessary to state, that on the same day on which Lisbon was nearly destroyed, all Europe, and a great part of northern Africa, felt the shock more or less severely: its effects were also sensible across the Atlantic, both in the United States and the West Indies. Incredible as it may seem, one fourth of the northern hemisphere was agitated by the same earthquake. The bed of the Atlantic was raised above the surface of the ocean, and flame and vapor were discharged: this was observed by vessels at sea. If we take a terrestrial globe, and cover those parts of it that were thus affected by the earthquake with black crape, we shall obtain a more distinct idea of the extent of surface shaken, than a mere verbal description can convey. This appears to have been one of the most severe shocks that the old continent had experienced for several centuries. The cause which could effect a simultaneous concussion over such a vast extent, must probably have been seated nearly midway, between the centre of the globe and its surface.

It has been remarked, that, in general, earthquakes are more severely felt in mountainous than in low countries: this might be expected, from the structure of the earth.* In alpine districts the primary mountains are not pressed with the incumbent mass of secondary rocks; and, consequently, in such situations, the resistance to a force acting from beneath will be much less, as all the weight of secondary rocks is removed. In very violent earthquakes, the secondary strata are broken or agitated, but proofs are not wanting, of lesser vibrations being stopped by their pressure. Humboldt says, he has seen workmen hasten from the mines of Marienburgh, in Saxony, alarmed by agitations of the earth that were not felt at the surface. During the earthquake at Lisbon, the miners in Derbyshire felt the rocks move, and heard noises, which were scarcely perceived by those above. That an expansive force acting from beneath is the proximate cause of earthquakes, can scarcely be denied, and the prodigious power of steam, when suddenly generated, seems equal to their production, if the quantity be sufficiently great. It is said that a single drop of water falling into a furnace of melted copper, will blow up the whole building. This may be an exaggerated statement, but the prodigious force of steam at high temperatures is well known, and there can be no difficulty in admitting, that if a current of subterranean water were to find access to a mass of lava many miles in extent, and most intensely heated, it would produce an earthquake more or less violent in proportion to the quantity of steam generated, and its distance from the surface. When the hydrogen gas exploded in a mine near Workington, in Cumber-

* See a paper on Earthquakes, by the Rev. Mr. Mitchell, Philosophical Transactions, 1759.

land, a shock like that of an earthquake was felt by ships in the river, at two miles distance.

The horrid crash, like the rattling of carriages, which precedes earthquakes, may be occasioned by the rending of the rocks, or parting of the strata, through which the confined vapor is forcing a passage.

Towns situated on the coast, and nearly on a level with the sea, frequently experience the most destructive effects from a sudden rise of the water during earthquakes. An immense wave is thrown with much violence over the houses, and, on retiring, carries with it the ruins left by the earthquake, and scatters them on the coast, or deposits them in the ocean. The loss of life and property is often greater from this cause than from the previous agitation of the ground. This destructive wave is raised by a sudden eruption of gas and vapor under the sea, (often accompanied with flames,) which upheaves the water immediately over it, sometimes twenty or thirty feet; then descending nearly as much below its level. An immense wave is thus formed, and propelled upon the land, then retires with great violence, and returns again, until the equilibrium is restored.

During the late earthquake on the coast of Chili, (February, 1835,) the effects of these destructive waves were noticed by the officers of the Adventure and Beagle, who were on a surveying voyage off the coast at the time of the earthquake. The earthquake began at the city of Concepçion, at forty minutes past eleven; the sky was clear, and no notice was given of its approach: "the horrid motion increased; buildings waved and tottered; suddenly an awful overpowering shock caused universal destruction. In less than six seconds, the city was in ruins. The earth opened and shut rapidly and repeatedly, with horrible cracking. Besides a waving or undulating motion, vertical, horizontal, and circular or twisting motions were felt. An angular stone pinnacle was turned half round, without being thrown down, or leaving its base."—"At Tabahuana, the great earthquake took place at the same time, and in a similar manner. Three houses only escaped; the inhabitants fled to the heights. When the sea was observed to retire, so that vessels at anchor in seven fathoms water were aground, and all the rocks and shoals in the bay were visible, an enormous wave was seen forcing its way between the western passage, which separates Quiriquina Island from the main land. This immense wave passed rapidly along the western side of the Bay of Concepçion, sweeping the steep shore of every thing movable, within thirty feet, vertically, from the high-water mark. It broke over, dashed along, and whirled about the shipping, as if they had been light boats; it overflowed the greater part of the town, and then rushed back with such a torrent, that almost every thing movable, which the

earthquake had not buried, was carried out to sea. In a few minutes, a second wave returned, more powerful than the first. After another awful suspense of a few minutes, a third enormous swell was observed approaching, larger than either of the former waves. Two explosions, or eruptions, were seen in the offing, while the waves were coming in. One was seen by Mr. Henry Burdon and family, who were then embarked in a large boat; it appeared to be a dark column of smoke, in shape like a tower. Another arose in the middle of the Bay of San Vincente, like the blowing of an immense imaginary whale: its disappearance was followed by a whirlpool, which lasted some minutes; it was hollow, as if the sea was pouring into a cavity of the earth. Until after the great waves, the water in the bay appeared to be every where boiling: it also became black, and exhaled a most disagreeable sulphureous smell. In Mr. Evans's yard at Tabahuana, the ground swelled like a large bubble; and then, bursting, poured forth black sulphureous water. The Island of Juan Fernandez suffered much. An eruption burst from the sea, about a mile distant from the land, where the depth is from fifty to eighty fathoms. Smoke and water were thrown out during the day; flames were seen at night. Great waves swept the shores of the island, after the sea had retired, so much that old anchors were seen at the bottom of the anchorage."—"The earthquake was felt at all places between Chiloe and Copiapo, and between Juan Fernandez and Mendoza. On the sea coasts within these limits, the retiring and swelling of the ocean were every where felt. On the continent, nearly all the towns and cities between the parallel of thirty-eight and thirty-five degrees of latitude were ruined. One of the most noticeable circumstances attending this earthquake, was the permanent upheaving of the ground. The Island of Santa Maria was ascertained to have been upheaved nine feet. The Beagle visited this island twice, to examine the fact. By this elevation, the southern port of Santa Maria has been almost destroyed. The soundings have diminished a fathom and a half every where round the island. At Tubal, to the southeast of Santa Maria, the land has been raised six feet." See *Journal of the Royal Geographical Society of London*, Vol. VI, Pt. II.—This account strongly corroborates the evidence of Mr. Graham (given elsewhere in the present volume) respecting the upheavement of the coast of Chili, during the earthquake of 1822.

All the phenomena that accompany earthquakes, indicate the intense operation of elastic vapor, expanding and endeavoring to escape where the least resistance is presented, and producing vibrations of the solid strata. The intimate connection between earthquakes and volcanic agency, is too obvious to require much illustration. All volcanic eruptions are preceded by earthquakes

of greater or lesser extent; but all earthquakes are not attended by volcanic eruptions. The elastic vapor may sometimes find vent through existing fissures and apertures; or the aqueous vapor may meet with subterranean currents of cold water, and suddenly collapse, producing a second earthquake in a contrary direction. In common language, the agitation of the ground, when the surface is not broken, is called the shock of an earthquake. Since the records of history, there have been no earthquakes in Great Britain equal in intensity to what have taken place in the southern parts of Europe. In the year 1247, a general earthquake is said to have extended over England; it threw down the church of St. Michael's on the Hill, at Glastonbury. The greatest earthquake recorded in England took place Nov. 14th, 1318. On April the 6th, 1580, an earthquake, felt in London and Westminster, threw down a part of St. Paul's church, and of the Temple church. Perhaps, in the present time, ten years seldom elapse without the shock of an earthquake being felt in some part of Great Britain: but these are too feeble to require historic notice. We have evidence, however, of mighty earthquakes having shaken the surface of this part of the globe. The faults and dislocations of the strata, of which some account has been given in different parts of the present volume, must have been accompanied, during their formation, with more violent agitation of the ground than any recorded in history; but it is probable that, at that period, the land which now forms Great Britain, had only partially emerged from the ocean.

After the discovery of the Leyden Phial, many natural phenomena were ascribed to electric action, and earthquakes were supposed to be the result of electric shocks, acting with great intensity in the interior of the earth. The electric theory of earthquakes was soon discarded as untenable; but now the identity of magnetic and electric agency seem, in many respects, to be established, it may deserve consideration, whether an interruption to the magnetic or electric currents which circulate through the earth, may not sometimes occasion earthquakes, acting almost instantaneously over large portions of the globe.

If, as some philosophers maintain, there is a central fire under every part of the globe, or if certain spaces only are filled with ignited matter, we can scarcely doubt, that chemical changes are taking place, which will also change the electrical relations between mineral beds. A series of strata may act like the plates of an immense voltaic battery, and discharge the electricity from one internal part of the globe to another, exciting vibrations that may agitate a whole hemisphere. I was informed by a gentleman who resided several years near the feet of the Himmahlaya mountains, that peals of subterranean thunder were sometimes heard, which resembled atmospheric thunder, but were incon-

ceivably louder and more appalling; they were followed by earthquakes. Humboldt also mentions the frequency of subterranean thunder in some districts bordering on the Andes.

In volcanic phenomena, we observe a cause in present activity that can overthrow mountains, form new islands, and raise up the bed of the ocean: hence the geologist may infer, that the same cause, acting with greater intensity and more extensively, has been the agent employed by the Author of nature, to elevate new, and submerge ancient continents, and to change and renovate the surface of the globe. We are indeed acquainted with no other natural agent, that can have effected the mighty changes which the crust of our planet has undergone. The products of volcanoes, particularly of ancient ones, are analogous in their composition and internal structure to the oldest rocks of granite, sienite, and porphyry, and indicate, not obscurely, the mode in which these rocks were formed: hence the study of volcanoes and volcanic rocks, is an important branch of the science of geology. Werner and his disciples, however, held that volcanoes were merely produced by the ignition of beds of coal, in the secondary strata.

Volcanoes are openings made in the earth's surface by internal fires; they regularly, or at intervals, throw out smoke, vapor, flame, large stones, sand, and melted stone called lava. Some volcanoes throw out torrents of mud and boiling water. Volcanoes most frequently exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the surface of the ocean, and form new islands and reefs of rock. When a volcano breaks out in a new situation, it is preceded by violent earthquakes, the heated surface of the ground frequently swells and heaves up, until a fissure or rent is formed, sometimes of vast extent. Through this opening, masses of rock, with flame, smoke and lava, are thrown out, and choke up part of the passage, and confine the eruption to one or more apertures, round which conical hills or mountains are formed. The concavity in the center is called the crater.*

The indications of an approaching eruption from a dormant volcano, are an increase of smoke from the summit, which sometimes rises to a vast height, branching in the form of a pine tree. Tremendous explosions, like the firing of artillery, commence after the increase of smoke, and are succeeded by red-colored flames, and showers of stones. At length the lava flows out from the top of the crater or breaks through the sides of the mountain, and covers the neighboring plains with melted matter, which, becoming consolidated, forms a stony mass, often not less than some hundred

* Craters formed in the manner here described are called 'Craters of Eruption.' Craters which appear to have been formed by the upheaving of the ground, attended with volcanic ejections, are called 'Craters of Elevation.'

square miles in extent, and several yards in thickness. The eruption of lava has been known to continue several months. Intensely black clouds, composed of a kind of dark colored sand or powder, improperly called ashes, are thrown out of the crater after the lava ceases to flow, and sometimes involve the surrounding country in total darkness at noon-day. Towards the conclusion, the color of the volcanic sand changes to white: it consists of pumice in a finely comminuted state. During an eruption of Ætna, a space of one hundred and fifty miles in circuit was covered with a stratum of volcanic sand or ashes twelve feet thick. When the lava flows freely, the earthquakes and explosions become less violent, which proves that they were occasioned by the confinement of the erupted matter, both gaseous and solid. The smoke and vapor of volcanoes are highly electrical.

The quantity of lava thrown out during a single eruption of a volcano, seems almost incredible to those who have not observed volcanic countries. In the year 1669, a current of lava from Ætna covered an extent of eighty four square miles; and again in 1775, according to Dolomieu, the same volcano poured out another stream of lava, twelve miles in length, one mile and a half in breadth, and two hundred feet in height. The largest known current of modern lava was formed by a volcano in Iceland in 1783; it is sixty miles in length, and twelve broad, equalling in extent any continuous rock formation in England. Hence it is evident, that the seat of the fire is not in the mountain itself, but deep in the earth: the volcano is not the furnace, but the chimney; and it will be necessary to bear this in mind, if we would form an adequate idea of the extensive effects of volcanic action. Seneca appears to have had a distinct notion of the seat of volcanic fire, when he remarks, that the volcano does not supply the fire, it only affords it a passage, "*in ipso monte non alimentum habet, sed viam.*" The most extraordinary volcanic eruption recorded in history for the extent of its effects, took place in Sumbawa, one of the Molucca Islands, in April, 1815. It is described in the history of Java, by Lieutenant Governor Raffles.

"This eruption extended perceptible evidences of its existence over the whole of the Molucca Islands, over Java, a considerable portion of Celebes, Sumatra, and Borneo, to a circumference of a thousand statute miles from its center, by tremulous motions and the report of explosions; while within the range of its more immediate activity, embracing a space of three hundred miles around, it produced the most astonishing effects, and excited the most alarming apprehensions. In Java, at the distance of three hundred miles, it seemed to be awfully present. The sky was overcast at noon-day with clouds of ashes; the sun was enveloped in an atmosphere, whose 'palpable' density he was unable to penetrate; showers of ashes covered the houses, the streets,

and the fields, to the depth of several inches; and amid this darkness, explosions were heard at intervals, like the report of artillery or the noise of distant thunder. So fully did the resemblance of the noises to the report of cannon impress the minds of some officers, that, from an apprehension of pirates on the coast, vessels were dispatched to afford relief. Superstition on the other hand was busily at work on the minds of the natives, and attributed the reports to an artillery of a different description to that of pirates. All conceived that the effects experienced might be caused by eruptions of some of the numerous volcanoes on the island; but no one could have conjectured that the showers of ashes which darkened the air and covered the ground of the eastern districts of Java, could have proceeded from a mountain of Sumbawa, at the distance of several hundred miles."

The lieutenant governor of Java directed a circular to the different residents, requiring them to transmit to the governor a statement of the facts and circumstances connected with this eruption. The most remarkable circumstance attending this eruption, is the distance at which the explosions were heard in the islands of the Indian Sea. "From Sumbawa, to the part of Sumatra where the sound was noticed, is about nine hundred and seventy geographical miles. From Sumbawa to Ternate, is a distance of about seven hundred and twenty miles. The distance to which the cloud of ashes was carried so thickly, as to produce utter darkness, was clearly pointed out to be the island of Celebes, and the district of Grisik in Java; the former two hundred and seventeen nautical miles in a direct line, the latter more than three hundred geographical miles." The greatest distance at which the eruption of any volcano had been previously heard, is six hundred miles: according to M. Humboldt, the explosions from Cotopaxi are sometimes sensibly heard at that distance from the volcano, which is one of the largest and highest in the American continent.

The long period of repose which sometimes takes place between two eruptions of the same volcano, is particularly remarkable. From the building of Rome to the 79th year of the Christian era, no mention is made of Vesuvius, though it had evidently been in a prior state of activity, as Herculaneum and Pompeii, which were destroyed by the eruption of that year, are paved with lava. From the 12th to the 16th century it remained quiet for nearly four hundred years, and the crater was overgrown with lofty trees. The crater was descended by Bracchini, an Italian writer, prior to the great eruption of 1631: the bottom was at that time a vast plain, surrounded by caverns and grottoes. Ætna has continued burning since the time of the poet Pindar, with occasional intervals of repose, seldom exceeding thirty or forty years.

The eruptions of the Peak of Teneriffe have been very rare during the last two centuries. According to Humboldt, "the long intervals of repose appear to characterize volcanoes highly elevated. Stromboli, which is one of the lowest, is always burning; the eruptions of Vesuvius are rarer, but still more frequent than those of Ætna. The colossal summits of the Andes, Cotopaxi, and Tungurahua, scarcely have an eruption once in a century. The Peak of Teneriffe seemed to be extinguished for ninety-two years, when it made its last eruption by a lateral opening in 1798. In this interval Vesuvius had sixteen eruptions." The greatest eruptions of lava from Ætna and Vesuvius are always from the sides of these mountains, but these lateral eruptions finish by an ejection of ashes and flames, from the crater at the summit of the mountain. In the Peak of Teneriffe, an eruption of lava from the summit has not taken place for ages; and in the recent great eruption of 1798, the crater remained inactive, nor did its bottom fall in.

The observation of M. Humboldt, that lofty volcanoes have the longest periods of repose, will not be found universally correct. The small volcano of Vulcano, one of the Lipari islands, was in a dormant state for thirteen hundred years, while the volcano of Popocatapetl, fourteen leagues from Mexico, which is nearly eighteen thousand feet above the level of the sea, seems to be in a state of constant activity. It was ascended by Lieutenant William Glennie, in 1827. "The volcano rises from a country that is 8216 feet above the sea; its sides are thickly wooded with pine forests to the height of nearly 13,000 feet: beyond this altitude vegetation ceased entirely. The ground consisted of loose black sand of considerable depth, in which numerous fragments of pumice and basalt were dispersed; above this were several projecting ridges of loose fragments of basalt, arranged one above another. At the summit, the mercury subsided to 15.63 inches. The crater appeared to extend one mile in diameter; the interior walls consisted of masses of rock, arranged perpendicularly, and marked by numerous vertical channels, in many places filled with black sand. Four horizontal circles of rock, differently colored, were also noticed within the crater. From the edges of the latter, as well as from its perpendicular walls, several small columns of vapor arise, smelling strongly of sulphur. The noise was incessant, resembling that heard near the sea shore, during a storm. At intervals of two or three minutes, the sound increased, followed by an eruption of stones: the larger fell again into the crater, the smaller were projected into the ravine which we had ascended."

The volcano of Popocatapetl is perhaps the loftiest active volcano that has been ascended, and yet, according to Humboldt, it sometimes pours out currents of lava from the summit.

Those who are acquainted with hydrostatics, and know the immense power that would be required to raise even a column of water from the level of the sea to the top of Popocatapetl, Ætna, or Teneriffe, will not be surprised, that the lava forces itself out of the sides, and rarely rises to the top of the crater, in lofty volcanic mountains. It has been calculated, that the force required to raise a column of lava to the height of the summit of Teneriffe, (twelve thousand five hundred feet,) would be equal to that of one thousand atmospheres; and M. Daubuisson, who has made the calculation, states, that if an opening were effected in the volcano at the level of the sea, under the above pressure, the lava and stones would be forced out with a velocity equal to two hundred and seventy metres, or eight hundred feet per second. Tom. i. p. 173.

The elevation of volcanic craters varying, as Humboldt observes, from six hundred to eighteen thousand feet, must not only influence the frequency of their eruptions, but must modify also the quality of the substance ejected.—"Some volcanoes only eject lava from their sides, like Teneriffe, although it has a crater on its summit; others have lateral eruptions, as I observed at Antisana in Quito, at the height of thirteen thousand feet, and their summits have never been pierced. Others equally hollow in their interior, as many phenomena indicate, act only mechanically on the surrounding country, breaking the strata and changing the surface of the soil. Thus the volcanic mountain of Chimborazo, with its dome of volcanic porphyry (*trachyte*,) at the height of twenty-two thousand two hundred feet, has no permanent aperture on its summit or its sides: the small crater by which its eruptions are effected, is placed on the plain of Calpi. The volcano of Pichinca, fifteen thousand feet high, and which I have particularly studied, has never ejected a current of lava since the excavation of the present valleys. On the contrary, the volcano of Popocatapetl in Mexico, sixteen hundred, or according to Lieutenant Glennie, near eighteen hundred feet in height, pours out narrow currents of lava, like those from the smaller volcanoes of Auvergne or Italy."

Submarine Volcanoes.—Volcanoes that burst forth under the sea, are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapor, which take fire and roll in sheets of flame over the surface of the waves. Masses of rock are darted through the water with great violence, and accumulate till they form new islands. Sometimes the crater of the volcano, rises out of the sea during an eruption. In 1783, a submarine volcano broke out near Iceland, which formed a new island; it raged with great fury for several months. The island afterwards sunk, leaving only a reef of rocks. In December, 1720, a violent earthquake was felt at Terceira, one of

the Azores; the next morning a new island, nine miles in circumference, was seen, from the centre of which rose a column of smoke: it afterward sunk to a level with the sea. A small island was formed in 1811, by a submarine volcano, at a little distance from St. Michael's, one of the Azores: it was a mass of black rock, described by the captain of the Sabrina frigate, who witnessed its formation, to be equal in height to the high Tor at Matlock. A gentleman who visited the Azores in 1813, informs me that it has sunk down and disappeared: there is now eighty fathom water in the place.

Near Santorini, in the Grecian Archipelago, submarine volcanoes have repeatedly burst forth during the last two thousand years, and formed several new islands: three of the ancient eruptions are recorded by Pliny, Strabo, and Seneca. The last eruption was in the year 1767.

So recently as the year 1831, a submarine volcano broke out not far from the island of Sicily, attended with all the phenomena before described. It was visited by some French geologists in September, soon after the eruptions had so far subsided as to allow them to land. Its circumference was found by measurement to be seven hundred and eighty yards, its height about two hundred and twenty feet. It appeared to be composed entirely of scoriæ and loose volcanic fragments; in the centre of these were some hard globular blocks of lava, but they appeared to have been projected from the crater. The borders of the crater were about two hundred feet high on one side, and about forty on the other; the bottom was filled with orange-colored water, and covered with a thick froth. White vapors issued continually, not only from the surface of the water, which appeared to be in a state of ebullition, but from innumerable fissures in the whole ground, and from the adjacent sea. The black sand on one side of the island, for about fifty or sixty feet, appeared burning. Bubbles of gas or vapor rose apparently from the interior of the earth, and they threw up with a slight detonation volcanic sand and particles. This volcanic island had risen from the depth of about five or six hundred feet below the surface of the sea. M. Prévôt states his belief, that this volcano ejected currents of submarine lava, and though the island is composed of scoriæ and fragments thrown out of the crater, (which is what the French denominate a *Crater of Eruption*,) yet that it was preceded by an upheaving of the soil (*soulèvement*,) and that there is a belt of rocks at the base, which are the border of a crater of elevation (*cratère de soulèvement.*) M. Prévôt anticipated, that owing to the loose materials of which this island is composed, it would not long resist the action of the waves. Indeed the island appeared to have suffered considerable degradation before the French geologists landed, for Captain Senhouse, who visited it the preceding month, August 3,

stated its circumference to be about one mile and a quarter. According to Captain Swinburne, who observed some of the earliest eruptions from this volcano on the 19th of July, the external diameter of the crater was estimated at from seventy to eighty yards, it was not then more than about twenty feet above the sea. The agitated water in the crater escaped by an opening on one side: he says, "After the volcano had emitted for some time its usual quantities of white steam, suddenly the whole aperture was filled with an enormous mass of hot cinders and dust, rushing upwards to the height of several hundred feet, with a loud roaring noise; then falling into the sea on all sides, with a still louder noise. Renewed explosions of hot cinders and dust were quickly succeeding each other, while forked lightning, accompanied by rattling thunder, darted from all directions within the column now darkened with dust, greatly increased in volume, and distorted by sudden gusts and whirlwinds." The latitude of this island is, or rather was, 37° 11′ north, and longitude east 12° 44′.

At the beginning of January in the following year, the top of the island was somewhat below the surface of the sea, and at the latter end of February, soundings had been made at different times, which discovered depths of from fifty to one hundred and fifty feet, from the surface of the sea to the cone of the volcano. This sudden sinking down of the volcano, must be attributed to the subsidence of the ground beneath it.

Volcanic Eruptions of Water and Mud.—Some volcanoes in Europe, and many in the Andes, throw out aqueous torrents intermixed with mud and stones, indeed, the American volcanoes more frequently eject mud than lava. Eruptions of water from Ætna and Vesuvius are rare, and some, which have been described as flowing from the crater of the former, have been merely the torrents of melted water from snow on its summit. The volcano of Macaluba, in Sicily, presents the phenomena of mud, water, and stones thrown out of the crater. Ferrara describes an alarming eruption which took place on the 29th of September, 1777:—"Dreadful noises were heard all around; and from the midst of the plain, in which was formed a vast gulf, an immense column of mud arose to the height of about one hundred feet, which, abandoned by the impulsive force assumed the appearance of a large tree at the top. In the middle, stones of all kinds and sizes were darted violently and vertically, within the body of the column. This terrible explosion lasted half an hour, when it became quiet; but after a few minutes resumed its course, and with these intermissions continued all the day. During the time of this phenomenon, a pungent odor of sulphuretted hydrogen gas was perceived at a great distance, to the surprise of the inhabitants, who did not dare to approach this spot on account of the horrible noises. But many came the following day, and found

that the new great orifice had ejected several streams of liquid chalk (*creta*,) which had covered, with an ashy crust of many feet, all the surrounding space, filling the cavities and chinks. The hard substances ejected, were fragments of calcareous tufa, of crystallized gypsum, pebbles of quartz, and iron pyrites, which had lost their lustre, and were broken in pieces. All these substances form the outward circuit at this day. The unpleasant smell of sulphur still continued, and the water which remained in the holes was hot for many months; while a keen smell of burning issued from the numerous orifices around the great gulf, which is now completely filled."

The damage which aqueous and muddy eruptions in the Andes occasions, is often prodigiously great. Sometimes the deluge of water attending a volcanic explosion does not come from the interior of the earth, but from the snow which covers the mountain being rapidly dissolved; but in other instances it proceeds from the crater. Interior cavities of vast extent and depth, containg water, are opened during an eruption, and the water coming into contact with ignited lava, is forcibly driven out, and, according to Humboldt, carries along with it a great quantity of small fishes, which he has denominated *Pimelodes Cyclopum.** These fishes are about four inches in length, and are of the same species that inhabit the neighboring brooks and lakes: the number thrown out is sometimes so great, that their putrefaction contaminates the air, and occasions serious maladies among the inhabitants of the adjacent country.

Though the waters ejected from volcanoes may in many instances be regarded as of accidental occurrence, I conceive it to be different with those muddy eruptions, which cover large tracts of country with strata containing bituminous or inflammable matter: these strata are as essentially volcanic products, as the matter thrown out of the volcano of Macaluba in Sicily, which never ejects lava; and we are hence instructed, that one of the substances which promotes volcanic combustion, is bitumen or carbon. The muddy eruptions in the Andes, when first ejected, have little consistency or tenacity; but they soon become hard, and form what is called *moya;* it is dark colored and soils the fingers, and is used instead of turf for fuel.

Boiling springs, and thermal waters, must be classed with volcanic phenomena, for it can scarcely be doubted, that the geysers in Iceland, which throw up columns of boiling water at intervals, to the height of seventy or eighty feet, are occasioned by the subterranean fires which extend under that island. To the same

---

* It ought to be stated, that the existence of internal cavities filled with water supplied from the melted snow, is an inference from volcanic phenomena, which, however reasonable it may appear, it is impossible to prove.

cause must be ascribed the boiling fountains in the island of St. Michael, one of the Azores. The hot springs in the vicinity of the Pyrenees, in Italy, and in other parts of the world, may with much probability be supposed to have a similar source of heat. The unvaried equality of their temperatures for centuries, proves that this source lies far below the agency of those causes which operate on the surface. It has been remarked, that hot springs are most frequent in volcanic and basaltic countries. Though no active volcano exists in the Pyrenees, M. Dralet in his *Description des Pyrenées*, says, "that the hot springs and frequent earthquakes in different parts of this chain, offer proofs of the present operation of subterranean fires." I have described the thermal waters of the Alps in the second volume of my "Travels in the Tarentaise," and in Chapter V. of the present work.

Groups of Volcanoes.—Volcanoes frequently occur in groups, sometimes arranged along a line, as if they had originally been formed over one vast chasm, like the minor volcanoes on the sides of Ætna; sometimes they are dispersed irregularly over the surface, and sometimes they are isolated like Ætna and the Peak of Teneriffe.

The volcanoes in South America, Humboldt observes, instead of being isolated or dispersed in irregular groups as in Europe, are arranged in rows, like the extinct volcanoes of Auvergne, or the volcanoes of Java; sometimes in one line, and sometimes in two parallel lines. These lines are generally in the same direction, as the chain of the Cordilleras, but sometimes (as in Mexico) they form an angle with it of 70°. The volcanoes of Mexico, he further observes, are placed in a narrow zône, between latitude 18° 59′ and 19° 12′. This he regards as a vast chasm, seven hundred and fifty miles in length, extending from the coast of the Atlantic to that of the Pacific, and to the islands of Revillagiedo in the same direction.

Our knowledge of volcanic geography is at present imperfect, but among the principal volcanic groups and ranges, the following may be briefly enumerated:—

In the Azores there are no less than forty-two active or dormant volcanoes; and submarine volcanoes not unfrequently break forth in their vicinity. Almost all the other islands in the Atlantic, and many of the West Indian islands, are volcanic. Numerous islands in the Pacific Ocean and the Indian Seas have large volcanoes. In the island of Java alone, there is a range, consisting of thirty-eight large volcanic mountains, some of which are at present in an active state; they are detached from each other, and though some of them are covered by the vegetation of many ages, the indications of their former eruptions are numerous and unequivocal.

Numerous volcanoes exist, near or within the arctic circle, in Kamschatka, in Greenland, and in Iceland. A range of active or dormant volcanoes extends from the southern extremity of America to the northern, along a line of six thousand miles in length. Of the volcanoes in northern Asia, or the interior of Africa, we have little information, and the volcanoes covered by the sea cannot be estimated; but from the above statement we are authorized in believing, that volcanic fires are more extensively operative, than many geologists are disposed to admit.

Many facts might be cited, to prove the connection which exists between volcanoes at a vast distance from each other. In 1783, when a submarine volcano near Iceland suddenly ceased its eruptions, a volcano broke out two hundred miles distant, in the interior of the island. On the night in which Lima and and Callao were destroyed by an earthquake, four new volcanoes broke out in the Andes. The source of volcanic fire is seated deep under the surface of the earth: were it not so, the ground in the vicinity of volcanoes would sink down. Ætna has continued to throw out streams of lava for three thousand years; and Stromboli has had daily eruptions for nearly as long a period.*

Destruction of Volcanoes.—There are some instances of volcanoes having been entirely engulfed in the chasms beneath them. The volcano of the Pic in the Island of Timore, one of the Moluccas, is known to have served as a prodigious watch light, which was seen at sea at the distance of three hundred miles. In the year 1638, the mountain during a violent eruption, entirely disappeared, and in its place there is now a lake. Many of the circular lakes in the south of Italy are supposed to have been formed by the sinking down of volcanoes; but the best authenticated account we have of the destruction of a volcanic mountain, is given by Governor Raffles in his History of Java.

"The Papandayang, situated at the western part of the district of Cheribor, in the province of Sukapura, was formerly one of the largest volcanoes in the island of Java; but the greatest part of it was swallowed up in the earth, after a short but very

---

* Since the period of authentic history, no great changes have taken place in the country round Ætna; but it appears from Virgil, as well as from a passage in Strabo before quoted, that an ancient tradition existed of the sudden separation of Sicily from Italy.

> "Hæc loca, vi quondam et vastâ convulsa ruinâ
> Dissiluisse ferunt: cùm protinus utraque tellus
> Una foret, venit medio vi pontus, et undis
> Hesperium Siculo latus abscidit: arvaque et urbes
> Littore diductas angusto interluit æstu." *Æn.* l. iii.

Probably this separation took place when Ætna emerged from the ocean: the occurrence of beds of limestone with shells upon its sides, proves that it was originally a submarine volcano.

severe combustion, in the year 1772. The account which has remained of this event, asserts, that near midnight, between the 11th and 12th of August, there was observed about the mountain an uncommonly luminous cloud, by which it appeared to be completely enveloped. The inhabitants, as well about the fort as on the declivities of the mountain, alarmed by this appearance, betook themselves to flight; but before they could all save themselves, the mountain began to give way, and the greatest part of it actually *fell in*, and disappeared in the earth. At the same time, a tremendous noise was heard, resembling the discharge of the heaviest cannon. Immense quantities of volcanic substances, which were thrown out at the same time, and spread in every direction, propagated the effects of the explosion, through the space of many miles.

"It is estimated that an extent of ground of the mountain itself, and its immediate environs, fifteen miles long, and full six broad, was by this commotion swallowed up in the bowels of the earth. Several persons, sent to examine the condition of the neighborhood, made report, that they found it impossible to approach the place where the mountain stood, on account of the heat of the substances which covered its circumference, and which were piled on each other; although this was the 24th of September, and thus full six weeks after the catastrophe. It is also mentioned, that forty villages, partly swallowed up by the ground, and partly covered by the substances thrown out, were destroyed on this occasion, and that two thousand nine hundred and fifty seven of the inhabitants perished. A proportionate number of cattle was also destroyed, and most of the plantations of cotton, indigo, and coffee, in the adjacent districts, were buried under the volcanic matter. The effects of this explosion are still very apparent in the remains of this volcano."

Ancient Extinct Volcanoes.—However powerful the effects of subterranean fire may be in various parts of the globe, we must conclude, from the remains of ancient volcanoes, that in a former period, the action of volcanic fire has been far more extensive and intense than at present.

According to Breislak, an Italian geologist, in a space of twenty miles in length and ten in breadth, between Naples and Cumea, there are no less than sixty craters; some of them are larger than that of Vesuvius. One of them is two miles in diameter. The city of Cumea, founded twelve hundred years before the Christian era, is built in the crater of an ancient volcano.

In other parts of Italy, there are undoubted vestiges of ancient volcanoes. In Sicily, there are a number of extinct volcanoes, beside those connected with Etna. Many islands in the Grecian Archipelago are volcanic. There are remains of large volcanic craters in Spain and Portugal; and the extinct volcanic moun-

41

tains in the middle and southern parts of France, cover several thousand square miles. On the eastern banks of the Rhine, and the environs of Andernach, there are numerous extinct volcanoes.

It is further to be noticed, that the craters of ancient volcanoes are, many of them, of far greater size than the present ones. Vesuvius is a comparatively small cone, raised within the crater of a larger volcano. The cone of the Peak of Teneriffe, according to the description of travellers, stands within a volcanic plain, containing twelve square leagues of surface, surrounded by perpendicular precipices and mountains, which were the border of the ancient crater. If the opinion of M. Humboldt be correct, all these craters are diminutive apertures, compared with the immense craters through which, in remote ages, subterranean fire had forced a passage through the crust of the globe.

"The whole of the mountainous parts of Quito," he says, "may be considered as one immense volcano, occupying more than seven hundred square leagues of surface, and throwing out flames by different cones, known by the denominations of Cotopaxi, Tungurahua, and Pichincha. In like manner," he adds, "the whole group of the Canary Islands is placed, as it were, on one submarine volcano. The fire forces a passage, sometimes through one and sometimes through another of these islands. Teneriffe alone, contains in its centre an immense pyramid, terminated by a crater, throwing out, from one century to another, lava by its flanks. In the other Canary Islands, the different eruptions take place in various parts, and we no where find those isolated mountains, to which volcanic effects are restrained. The basaltic crust formed by ancient volcanoes, seems every where undermined; and the currents of lava seen at Lanzerote and Palma, remind us," he adds, "by every geological affinity, of the eruption which took place in 1301, at the Isle of Ischia, amid the tufas of Epimeo."

In the preceding part of the present chapter, I have endeavored to give a succinct account of the most important volcanic phenomena. The only hard crystalline rocks formed in the present day, are volcanic; and if we trace the connection that exists between modern and ancient volcanic rocks, and between the latter and the rocks of trap and porphyry, among the ancient rock formations, we shall extend the dominion of Pluto over a large portion of the globe.

Many of the ancient volcanic rocks have not flowed in currents from limited apertures, like modern lavas. "The volcanic porphyries on the back of the Cordilleras," says M. Humboldt, "are undoubtedly of igneous origin; but the mode of their formation is not like that of modern lavas, which have been erupted since the excavation of valleys. The action of volcanic fire by an isolated cone or crater of a modern volcano, differs necessa-

rily from the action of this fire, through the fractured crust of the globe." It has been observed by the same geologist, that the further back we can trace volcanic eruptions, the greater is the similarity between their products, and the rocks which are regarded as the most ancient;—hence the countries that have been the seats of ancient volcanoes, are particularly interesting to the geologist. In Auvergne, and the more southern parts of France, there are extinct volcanoes of different ages, covering with their products several thousand square miles. The most recent of these volcanoes has been extinct or dormant since the records of authentic history, and probably for a longer period. Julius Cæsar, who was encamped on this volcanic soil, and has described the country, makes no allusion to its having been the seat of active volcanoes.*

West of the town of Clermont, there is an extensive granitic plain, rising about sixteen hundred feet above the level of the river Allier. On this plain there are numerous cones, and dome-shaped hills, varying in height from twelve hundred to two thousand feet; some of these cones have well-preserved craters, and the cones themselves are chiefly formed of scoriaceous lava. These are the most recent volcanoes of that country; their products differ in no respect from those of modern volcanoes, except that the lava may often be observed passing to the state of compact basalt, exactly similar to many of the basaltic rocks in Great Britain. That these volcanoes are the most recent, is proved by the lava having flowed down from them into the present valleys; and hence we are certain, that the eruptions must have taken place subsequently to the excavation of the valleys. There are other currents of lava from more ancient volcanoes, that have flowed before the valleys were excavated, and form isolated caps on the hills that enclose the present valleys. These currents of lava are composed chiefly of compact basalt: the position of these isolated caps of basalt is similar to that on the hill *b*, (Plate III, fig. 2,) but they are not always columnar. The openings from whence these beds of basalt have flowed, cannot be always traced; but as we can observe the change from scoriaceous lava to basalt in the currents of undoubted lava, we cannot hesitate to admit, that the basalt which forms these caps must have had a similar origin. Under the caps of basalt, there are in many situations thick beds of volcanic tufa, containing bitumen, which will

* I visited the extinct volcanoes of France in the spring of 1822, and published an account of them in the second volume of my Travels, accompanied with cuts, and a section and outline of the country round Clermont, which was, I believe, the first attempt to render in this manner the structure of this volcanic district intelligible to the general reader. Without the aid of sections and diagrams, it is difficult to obtain a distinct notion of the relative position of the different volcanic formations.

PUY DE PARIOU.

be subsequently noticed. Beside the volcanoes with craters, that have ejected currents of scoriaceous lava and basalt, and poured them into the valleys, and beside the more ancient volcanoes, that have formed beds of basalt before the excavation of the valleys,—there are other volcanic mountains, which have rounded summits, or domes, without any perforation or crater, and these are chiefly composed of whitish or grey earthy felspar, containing imbedded crystals of felspar: to this rock the name of trachyte has been given, on account of its rough fracture. It may be properly called a volcanic porphyry.

The more recent volcanoes resemble in every particular the existing volcanoes in various parts of the world; and the currents of lava may be traced from their sides along the granitic plain on which the volcanoes stand, and thence into the adjacent valleys for many miles. The lava appears as fresh as the recent lavas from Vesuvius, though it has been exposed to the action of the atmosphere for some thousand years. The Puy de Pariou is the most perfect of these volcanic cones: its height above the level of the sea, is four thousand and twelve feet, and above the granitic plain on which it rests, is about one thousand five hundred feet. The following description of it is taken from the second volume of my Travels:—"We were one hour in going from La Barraque, a mountain village, to the foot of the Puy de Pariou, where we left our char, and another hour in ascending to the summit, as we halted several times to rest. As nearly as I could estimate, the summit of this mountain rises about one thousand feet above the plain, and is therefore about three thousand eight hundred feet above the level of the sea. The crater, which is the best preserved of any in Auvergne, is nearly circular. I walked round it, and its circumference is about eight hundred yards. Its shape is that of an inverted cone or funnel, quite perfect. The edge or rim of the crater is narrow, from which the descent or slope is very rapid on each side: the depth of the crater, from the highest part of the edge (which is on the southern side) to the small plain at the bottom, may be about three hundred and twenty feet; and from the western side, about two hundred and sixty English feet. The lava which flowed from Pariou to La Barraque, and thence towards the plain of Clermont, is generally supposed to have issued from the crater; but had this been the case, the crater would not have been so entire as it is; and I am fully convinced, that the eruption of such a mass of lava must have broken down one of the sides, as at Nugere, which we afterwards visited, and the Puy de Vache. There appears, I think, decisive marks of the lava having flowed from an opening on the northeast side of the mountain, to which it may be traced. Indeed, on this side, there are the indications of a much larger crater, which has its escarpments turned towards the Puy de

Pariou, like those of Mount Somma, which are turned towards Vesuvius. The Puy de Pariou, was, in all probability, a volcanic cone, formed within the larger crater by its last eruption of scoriæ.

"The preceding cut, from a drawing I made near the foot of the mountain, represents the external shape of the Puy de Pariou, and the dotted lines show the form and the relative depth of the crater, the bottom of which, *a a*, is about three hundred and twenty feet below the highest part of the rim *c*. The current of lava, *b b*, is on the northeast side of the present mountain. The internal shape of Pariou approaches to quadrilateral, or is that of a cone compressed on each side, and somewhat elongated from north to south. The bottom of the crater is nearly flat; there was a little water, from the recent melting of the snow, remaining in some of the hollows: indeed, we were told at Clermont, that we should find the crater filled with snow. It was early in May: but the snow was gone, and grass was growing in some parts; others were covered with loose masses of scoriæ. Owing to the great porosity of the soil, the crater of Pariou seems doomed to perpetual sterility: there is no tree or shrub within it; while that of Vesuvius, after a cessation of eruptions for only four centuries, was covered with large chestnut trees."—Vol. II, p. 307.

In the Puy de Pariou, and many other volcanic mountains of this district, it is truly remarkable, that the lavas which flowed from them at a remote period, should preserve all the freshness of recent lavas; and that volcanoes so well characterized, both by their forms and mineral products, should have remained unnoticed until the middle of the last century.

A circumstance attending these more ancient eruptions, which deserves notice, is the bituminous nature of the tufa, that forms the lowest bed, and covers the fresh-water limestone of Gergovia, Canturges, and the neighboring hills. This tufa is in some parts more than three hundred feet thick; it consists of earthy basalt or wacke, intermixed with lumps of scoriæ and basalt, in some places united by a calcareous cement. It is every where impregnated with bitumen. The tufa of Auvergne bears evident marks of being the product of an aqueous or muddy eruption, intermixed with lava and scoriæ, which increase in quantity in the upper part of the mass, and at length become compact lava or basalt. That the tufa was ejected in an aqueous or muddy state, is proved by the quantity of bitumen which it contains; by any other mode of formation, the bitumen would have been consumed. By some former writers it has been supposed, that the tufa is an alluvial bed of sediment and water-worn fragments; but the bituminous nature of this bed excludes the probability of this mode of formation; and at Montadoux, the upper part of the tufa may be clearly seen passing into basalt. In some situations, how-

ever, the tufa has been transported from its original situation, and is intermixed with fragments of more ancient rocks.

The dome-shaped volcanic hills without craters, composed of porphyry or trachyte, have given rise to much speculation respecting their origin. It has been supposed that they were the remains of one vast bed of trachyte, and that the surrounding parts were carried away by diluvian agency; but this opinion is invalidated by the loose beds of scoria and fragments that now remain upon the soil,—a proof that no powerful currents of water have swept over the country, since the period of their eruption. It is now generally admitted, that the trachyte in Auvergne is only granite more or less perfectly fused, and that these rounded hills or domes of trachyte, have been upheaved by subterranean heat, without being opened or broken. On a grand scale, they may perhaps be considered as volcanic bubbles, that became consolidated without bursting. In the Island of Java, one of the trachytic mountains, called Jasinga, situated about twenty miles south of Batavia, rises in the form of a dome, somewhat flattened at the top; its elevation is about three hundred feet, and one hundred feet from the summit there is a small natural passage on the north side; this opens into a large vaulted cavity, in the middle of the mountain. The floor within descends rapidly, and there is a pool of water at the bottom. The floor is formed of tenacious slippery clay. There are several similar dome-shaped hills in the vicinity, but no passage into them has been discovered. No volcano or bed of lava can be traced near them.—*Bulletin de la Société Géologique de France*, Nov. 1834, p. 41.

The Puy de Dôme, one of the most remarkable volcanic domes in Auvergne, is, near the summit, chiefly composed of whitish trachyte, intermixed with unaltered granite; the lower part of the mountain is covered with scoriaceous and compact lava. The dome of this mountain rises 2000 feet above the elevated granitic plain on which it stands, and 4797 feet above the level of the sea: it has no crater or opening on the top, but Dr. Daubeny says, two streams of lava appear to have pierced the sides of the mountain, and to have descended into the valleys. In this respect the Puy de Dôme resembles the enormous dome of trachyte on the summit of Chimborazo, twenty thousand feet above the level of the sea. According to Humboldt, Chimborazo acts mechanically on the neighboring country, fracturing the strata, and changing the surface of the soil; but it has no permanent opening, neither on its summit nor sides.

In some of the dome-shaped hills in Auvergne, the action of subterranean heat appears to have been so intense as to have reduced the whole into a spongy pulverulent mass; but, what is remarkable, in the middle of this spongy mass, lumps of scoriaceous lava are sometimes found. The following cut represents

The church marks the position of the city of Clermont; No. 1. the Puy de Dôme; 2. the Puy de Cliersou; 3. Sarconi. These three mountains are domes of trachyte. 4. The Volcano of Pariou, of which a cut is given, page 324. 5. The position of La Barraque, a mountain inn. 6. Montadoux, composed of volcanic slag and tufa, in the lower part; the upper part is basalt.

the outline of the volcanic mountains on the northwest of Clermont, which I drew from the Puy de Cruelle.

In the volcanic districts south of Clermont, the porphyry becomes more compact, and assumes the hardest and most compact state of that rock. The base of the stone is sometimes green, and the crystals of felspar white: it will receive a fine polish, like the green porphyry of the ancients.

The basaltic rocks also extend south of Clermont, into the districts called the Velay and Viverrais, and cover a great portion of the soil. Near Monpezat, Thueys, and Jaujac, according to M. Faujas St. Fond, there are small volcanic mountains, with distinct currents of lava, that appear to have issued from their feet, and flowed into the valleys. The lower part of the lava is scoriaceous, but the upper part is hard sonorous basalt, arranged in columns as perfect as those of Staffa or the Giant's Causeway. We have here a decisive proof of the igneous formation of columnar basaltic rocks. "The basaltic formation extends into the South of France, to the borders of the Mediterranean Sea, where near to Adge, is the extinct volcano of Saint Loup, the cellular lava of which is employed in the construction of buildings on the canal of Languedoc."—*Daubuisson.*

There are numerous extinct volcanoes in several parts of Germany, particularly in some of the districts bordering the Rhine: these volcanoes, like those of central France, belong to different epochs, but the most recent appear to be more ancient than the earliest periods of authentic history. In the volcanic district of Eyfel, between the Rhine and the Moselle, are scattered numerous small cones and eminences, some with craters, the bottoms of which are filled with water, forming lakes or meres, without outlets. A German geologist divides these volcanoes into three classes:—

1. Those which have lakes or meres, and have ejected nothing but loose fragments of rock with balls of scoriæ and sand: of these there are eight in that district.
2. Those which have ejected fragments of slag, sometimes loose, and sometimes cemented: of these there are eight.
3. Those which have ejected streams of lava: of these, six are enumerated.

According to Dr. Daubeny, who has visited these craters, the currents of lava have not been satisfactorily traced to their source, being sometimes buried under heaps of volcanic matter subsequently ejected. These volcanoes rise through transition rocks of slate and limestone. The Seven Mountains near Bonn, belong to a very remote volcanic epoch. Those readers who intend to visit the countries near the Rhine, will do well to consult Dr. Daubeny's work on volcanoes, in which will be found the best information respecting the extinct volcanoes of Germany.

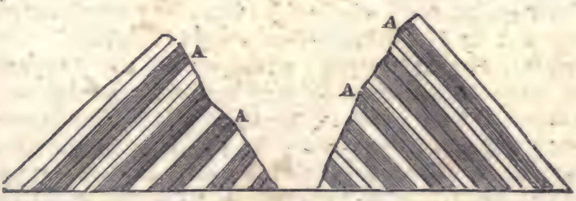
In proportion as the surface of the earth becomes properly examined, our knowledge of extinct volcanoes is enlarged in various countries. According to Burckhardt, there are several volcanoes in Arabia; one broke out near the city of Mecca, some centuries after its submission to the Mahometan faith. Extinct volcanoes are traceable in the vicinity of Mount Sinai, and from thence to the Dead Sea. The indications of volcanic action in Persia, and in various parts of the Asiatic continent, are too numerous to be cited: some of the mountains far removed from the sea, still emit smoke and vapor.

Craters of Elevation.—Cratères de Soulèvement.—Beside the craters of eruption, before described, the eminent geologists Von Buch and M. Elie de Beaumont maintain, that many of the largest volcanic mountains were not formed by successive eruptions of lava and scoriæ, covering each other, but are composed of beds originally horizontal, or nearly so, which have been raised by subterranean agency to their present elevation, before any passage for volcanic eruptions had been opened. Suppose successive beds of lava were poured through a chasm over the bottom of the ocean, and were consolidated over each other, filling and covering the chasm, through which they had been erupted. In a future volcanic paroxysm, the lava being prevented from ascending through the former opening, and the force acting with compressed intensity, might upheave the beds of submarine lava, and the subjacent rocks, to a considerable height above the sea, before a new passage was opened for a subsequent eruption. This would be a crater of elevation. With the ancient lava, the lower beds of granite or other rocks might also be raised up. This mode of volcanic operation is so analogous to that which has upheaved mountain masses in every part of the globe, that I am at a loss to conjecture on what principle it has been objected to. Let the reader refer to the position of the beds at Wren's Nest Hill, near Dudley, and their contiguity to basalt (Plate III, fig. 4,); or, what may be more directly to the purpose, let him turn to the section of Crich Cliff, (page 141,) in which the strata encircle and cover the hill, like the coats of an onion, and in which there is a mass of toadstone near the center. Few geologists will deny that the beds have been upheaved by a power acting from beneath, or that the protrusion of beds of volcanic toadstone was the original cause of the elevation of the strata. If the upheaving power at Crich Cliff had been increased in intensity, and a passage been opened near the summit, through which streams of lava and showers of scoriæ had been projected, we should have had a crater of elevation, though its structure and mode of formation might have been concealed by volcanic substances covering the original rock. Von Buch and Humboldt have been challenged to discover a single volcanic cone, composed exclusively of marine

or of fresh-water strata, but surely this is overlooking the conditions under which such a cone must be formed: the eruptions from the crater, when once open, would cover a great part of the external cone with lava and volcanic matter. The above eminent geologists might show Crich Cliff and Wren's Nest Hill, as presenting a triumphant confirmation of the theory of elevation; a confirmation not the less satisfactory, because the volcanic action had been arrested precisely at the point where the truth of the theory was rendered most apparent.

The island called the New Kamenoi, raised near St. Erini during a submarine eruption, in the year 1707, was partly composed of limestone, and was covered with living shells, which prove that the rock was upraised in a solid mass.

The theory of the formation of craters of elevation, does not, however, depend for its support on isolated instances, like that of the New Kamenoi, nor on hypothetical assumptions. If the structure and composition of various volcanic mountains have been correctly described, it may be satisfactorily proved, that they could not have been formed by volcanic eruptions. Thus if an elevated volcanic mountain, with a crater rising at a considerable angle above the surrounding country, be composed of different beds of compact lava, or of alternating beds of lava and scoriæ, as represented in the annexed section, it is impossible that these



beds of lava could have been originally deposited in their present position. Lava when first ejected, is in a state of perfect fluidity, like melted metal from a furnace, and it could not adhere to the side of a steep mountain so as to form a thick bed, but would descend to the bottom with great rapidity, like water or any other fluid. Sir Wm. Hamilton and others assert, that Ætna and all volcanic mountains were formed by successive streams of lava, and showers of ashes or scoriæ, but M. Elie de Beaumont has ascertained, by the careful measurement of about thirty streams of lava round Ætna, and of a great many on Vesuvius, that a stream having an inclination of 6° or more, cannot possibly form a continuous mass; it falls so rapidly that it cannot acquire a thickness exceeding a few feet. "It is only when the inclination is not more than 3° that the mass can spread and accumulate to a considerable height. Now as the third part of Ætna rises with an inclination of 29° to 32°, it is clear that when a stream of

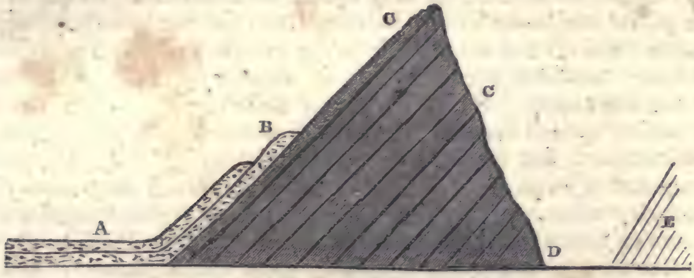
lava flows from the great crater it can produce very little effect, either as to the increase or the external form of the mountain. Even at the bottom of the *Val di Bove*, which is a great subsidence on the declivity of the volcano, the inclination of the streams being still 8° or 9°, and their thickness is hence so inconsiderable, that their course is recognised by their black color, and not by their bank-like continuation. The form of Ætna is regular, rising upon all sides with a uniformly advancing outline. The innumerable cones of eruption on the declivity, and round the base, stand like warts on this vast colossus; and the streams which flow from it so completely disappear at a short distance, that we must regard it as an absurdity to ascribe to them even the slightest influence in altering the form of the mountain."—*Edinburgh New Phil. Journal, Oct.* 1836.

The rapidity with which lava descends down the steep sides of the cone of Vesuvius, was observed at a distance by Messrs. Humboldt, Von Buch, and Gay Lusac, in the evening of the 12th of August, 1805, "A line of fire suddenly shot like lightning from the summit to the base, and remained fixed like a burning thread. Such currents have hardly ever a greater thickness than four feet; they pierce for themselves rapidly a deep and narrow furrow in the loose materials, and cannot extend in breadth."

The most decisive proofs of craters of elevation, are afforded by Mount Somma, the large ancient volcanic crater that surrounds Vesuvius, and by the *Monte Nuovo*, near Pozzuoli.

"Somma (says Von Buch) possesses all the characters of a crater of elevation so perfectly, that we may regard it as a model of this volcanic form; there is nothing which indicates a resemblance to a real stream of lava. The beds of lava with leucite, (*leucitephore*) of which it consists, are spread over a great part of the circumference, dipping at angles of from 20° to 30°, without any variation of their thickness, which is very considerable: a state of things completely at variance with the phenomena presented by streams of lava having so high an inclination. The elevation of this vast mountain in its full extent, is proved in a most striking manner, by the mode in which the Neapolitan tufa is disposed round the declivities of Somma. This tufa is a white porous rock, chiefly composed of pumice; it extends over the whole plain between the Apennines and the sea, it is found from Capua to the hills of Sorento, and from Nola to beyond Naples. The strata of tufa are almost always horizontal, reposing one above the other, and there the surface is perfectly level. These white strata of tufa, approach the Somma without interruption, but when they reach its base, they immediately ascend, rising with a high inclination to a certain height, where they stop, and the black beds of lava, which form the walls of Somma, succeed, and rise at a high angle and continue to the summit."

The reader may perhaps obtain a more distinct idea of this arrangement, from the annexed section of a side or wall of Somma, which is intended to explain the description given by Von Buch.



The beds of horizontal tufa, A, when they approach to Somma, are bent and raised upon its declivity to B, where they are seen to rest on elevated beds of dark lava, C C, of which the walls or escarpments of Somma are formed. D, the valley within the escarpment, between Somma and Vesuvius. Part of the volcanic cone of Vesuvius is represented at E.

The volcanic tufa, though chiefly composed of fragments of pumice (probably the result of some ancient submarine volcano,) was originally arranged in strata at the bottom of the sea, *as it contains in various parts marine shells imbedded within it, and in high preservation.* These strata of pumice are considered by Von Buch as tertiary formations; they were probably raised above the sea at the period of the elevation of the sub-Apennine strata mentioned in Chap. XVIII. The average height of the horizontal beds, A, is about 800 feet above the sea, but they are raised to the height of 1900 feet on the sides of Somma. The black lava, C, which rises from under the tufa, is about 1500 feet higher. The phenomena of elevation in Somma are so striking, that it appears impossible to resist the evidence they afford, if the facts have been correctly stated by Von Buch and his associates.

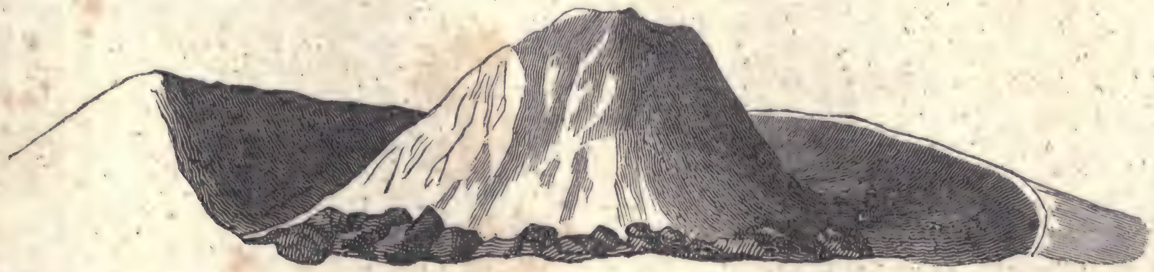
Monte Nuovo, a volcanic mountain near Pozzuoli, about 450 feet in height, was formed in a single day and night, on the 19th of September, 1538. After terrific earthquakes, the ground opened, and showers of pumice and scoriæ were thrown out. When the eruption ceased, a new mountain was seen, and a crater was found on its summit, more than 400 feet deep. This volcano has generally been cited as a crater of eruption, composed of scoriæ, pumice, and ashes, ejected during the darkness that took place at the time of its formation; but Von Buch informs us, that, on the 11th of December, 1834, he made the circuit of the crater, in company with Messrs. Elie de Beaumont and Dufrenoy. "On descending into the crater, we saw with the greatest distinctness,

on the declivities, the terminations of the strata, the rock of which the strata are composed could hardly be distinguished from the ordinary tufa of Posilipo. The inclination of the strata is to the exterior all around, as may easily be observed. In the interior of the crater, and in its bottom, there are black slags in large masses; and on the outer surface, the external covering is formed by large scattered porous blocks of altered trachyte, and other similar fragments. Had the internal walls of the mountain been formed of ejected masses, they would not be white, fine grained, and compact, but would only resemble shapeless conglomerates, composed of large and earthy fragments, to which they have no similarity whatever." *Monte Nuovo* must now be classed with craters of elevation, unless the correctness of Von Buch's observations can be disproved by subsequent examination.* It deserves notice, that at the time *Monte Nuovo* was formed, the country around was elevated ten feet above its former level, and the elevation has remained permanent. The description of the structure of Somma and Monte Nuovo is taken from an interesting article by Leopold Von Buch, 'On Volcanoes and Craters of Elevation,' translated from the German, and published in the Edinburgh New Phil. Journal, Oct. 1836. According to Von Buch, in many of the craters of elevation new cones arise, and become permanent volcanoes; in proof of this, he particularly cites the Peak of Teneriffe as an instance. At the sale of the late Faujas St. Fond's collection at Paris, I purchased two enormous shells of the gigantic cerithium, which (according to a notice written upon them by that geologist) were obtained from the Peak of Teneriffe: hence it appears, that this volcanic mountain was originally a crater of elevation, raised from under the sea.

A most remarkable instance of a mountain of granite elevated within the cone of a volcano, occurs in the lofty plain, west of Riom in Auvergne. This mountain is called the Puy de Chopine; it is nearly encircled by two segments of a volcanic cone, composed of scoriaceous lava, and fragments of compact lava intermixed with red ocherous earth.

The annexed cut represents the position of the Puy de Chopine within the crater, but the station from whence I took the sketch of the crater, was too near to comprise the view of the mountain. I took the outline of the latter, at a distance of some miles, on which account the size is too much diminished. I estimated its height from the crater in which it stands to be about 900 feet; according to M. Raymond its absolute height above the level of the sea, is 3910 feet. A great part of the mountain is composed of grey granite, red sienite, and hornblende, the granite in some

* The section of the crater, p. 331, with the strata dipping around from a central axis, will represent the arrangement of the strata in the crater of Monte Nuovo, but in this crater the strata are all composed of beds of tufa.



The Puy de Chopine, a granitic Mountain in the Crater of a Volcano.

parts appears to have been changed into trachyte. This singular intermixture of granite, sienite, and hornblende rock, with trachyte, within a crater composed of scoriæ and lava, seems to indicate, that the Puy de Chopine, had been elevated by subterranean heat, which was not sufficiently intense to convert the whole mass into trachyte, like that of the Puy de Dome. At the period of its elevation, there was probably an eruption of volcanic substances at its base, which formed the segments of the crater that nearly surrounds it. The mountain of granite was not (I now believe) projected into the crater of a volcano previously formed, but the eruption of volcanic scoriæ took place at the time the mountain was protruded. In my account of the Puy de Chopine given in the 2d vol. of Travels in the Tarentaise, p. 370, I considered the former mode of formation to be the most probable.

In the *Bulletin de la Societé Géologique de France*, Feb. 1834, there is a long and very interesting memoir, on the Craters of Elevation in Cantal, a volcanic district in the south of France, by M. Elie de Beaumont, which well deserves the attention of geologists. The facts and deductions it contains tend strongly to confirm the theory of craters of elevation. It cannot, however, be denied, that numerous volcanic craters of considerable magnitude, are formed by eruptions, for though streams of liquid lava, when first erupted, cannot consolidate into thick beds on the side of an elevated cone, yet the lava within the crater may penetrate into fissures laterly, and bind into a compact mass, the scoriæ, sand, and other loose materials of which the cone is composed.

From the various phenomena which volcanoes present, we may with probability infer, that the internal part of our planet is either wholly or partially in an igneous state, however difficult it may be to explain in what manner this heat is generated and confined. In every department of nature, our inquiries are terminated by ultimate facts, beyond which further research becomes vain. The constant generation and emission of light from the surface of the sun, is more inexplicable and surprising, than the constant generation of heat in the center of our planet; but we cannot refuse our assent to the fact, though it is far beyond the power of the human mind to conceive, by what means the particles of light are propelled through space with such astonishing velocity. We are too apt to measure natural operations by their coincidence with the received systems of philosophy, and to make our own ignorance the standard of truth. Had all the volcanoes in the world been dormant for the last two thousand years, and were we only acquainted with their existence by the writings of ancient historians, we should discredit the fact, and prove its impossibility, by an appeal to established chemical principles: we should further

accompany the proof, with a pathetic lamentation over the credulity of former times. The descent of stones from the atmosphere was denied during a longer period, though the fact is now established beyond all doubt.

Admitting the existence of central fire in the earth, it is not difficult to conceive, that there may be determinate causes by which its intensity is increased or diminished at certain periods. We know little respecting the operation of electric or voltaic energy in the laboratory of nature, but, from the existence of electric light at the poles, we may infer, that electric currents are passing through the earth, and are important agents in many subterranean phenomena. Perhaps the different beds of rock which environ the globe, may act like a series of plates in the voltaic pile, and produce effects commensurate with their vast magnitude. Voltaic energy is capable of supporting the most intense degree of heat without access to the atmospheric air, and even in vacuo; and this for an indefinite time.

Whatever origin we ascribe to subterranean fire, it must be recollected, that its action, when confined beneath the earth, is altogether different from that of fire on the surface, which changes and decomposes almost all substances exposed to its action. It is well known that the most inflammable substances, carbon and sulphur, undergo no change in their weight or properties when subjected to intense heat in vacuo. It is only when air or water obtain access to volcanic fire, that it can produce effects analogous to those of combustion on the surface. Indeed it appears probable, that volcanic explosions and earthquakes are occasioned by the access of water to subterranean fire. A sudden evolution of steam and vapor thus produced, will force a passage to the surface, in those parts where the incumbent rocks offer the least resistance, and the lava and fragments of rock will be ejected with a force, proportionate to the quantity of steam or air suddenly evolved.

Pseudo Volcanoes and Volcanic Products.—To the accidental combustion of beds of coal, the German geologists gave the name of Pseudo Volcanoes. There are instances of coal mines having been on fire many years; some of the mines of Belston in Staffordshire have been burning for a long period, but these fires are too limited in extent or activity to bear any comparison with volcanoes. The spontaneous combustion of beds of bituminous clay, intermixed with pyrites, are not very unfrequent. There is a pseudo volcano of this kind now in activity at Holwell Cliff, close to the Bay of Weymouth. The cliff is composed of Kimmeridge clay, and has become ignited by a rill of water behind it, which has penetrated into the clay. It constantly emits sulphurous vapor, and after heavy rains, fire is visible on the surface. In the last century the cliffs of lias near

Charmouth, took fire and continued burning for several months. When portions of the cliffs of alum shale near Whitby in Yorkshire fall upon the beach, and become moistened, they are sometimes spontaneously ignited. The same effect takes place in the Staffordshire coal mines; when parts of the bed of indurated clay which forms the roof of the coal fall down, and become moistened, it takes fire spontaneously: and hence this combustible clay is provincially called *tow*.

All these instances of spontaneous combustion admit of a satisfactory explanation. The cliffs of Charmouth and Whitby are composed of lias clay, much intermixed with bituminous and carbonaceous matter, and the sulphuret of iron (iron pyrites:) such is also the composition of the inflammable clay which forms the roof of the coal in Staffordshire; and the Kimmeridge clay near Weymouth is nearly similar in composition to the lias clay of Charmouth and Whitby, though it belongs to an upper part of the secondary strata. Iron pyrites abound in these cliffs; and it is a well known property of this mineral, to decompose rapidly when laid in heaps and moistened with water. During this rapid decomposition, sufficient heat is evolved to ignite the bituminous matter in the clay: and the clay, when once ignited, will burn for a long period:—this is proved in the process employed for making alum at Whitby. There can be little doubt that this spontaneous combustion might be imitated artificially by mixing pyrites and bituminous clay or shale, and moistening the heap with water. The experiment of Lemery is well known: he mixed twenty five pounds of powdered sulphur with an equal weight of iron filings; and, having made, with water, a paste of the mixture, he put it into an iron pot covered with a cloth, and buried it a foot under ground. In about eight hours the earth swelled and cracked, and hot sulphureous vapors were exhaled; a flame was observed to issue through the cracks, and the ground was covered with a yellow and black powder: thus a subterraneous fire was produced by the chemical combination of sulphur, iron, and water. In the cliffs of Charmouth, Whitby, and Weymouth, we have precisely the same mineral substances combined, that were used in the experiment of Lemery.

The earth itself is in all probability the great laboratory in which, by the aid of subterranean heat, are combined and prepared the mineral substances that compose the hard crystalline crust of the globe. All the minerals which form primary rocks, occur in a perfect state, in modern or ancient lava.

The substances ejected through fissures in the earth, or volcanoes, belong to the four grand divisions of the mineral kingdom, —the inflammable, saline, metallic, and earthy.

The *inflammable substances* are sulphur, carbon, and hydrogen. The inflammable quality of sulphur prevents its being found in

lava in a solid form: it is evolved in a gaseous state combined with hydrogen from volcanic apertures. It is also sublimed from fissures of extinct or dormant volcanoes, and forms thick incrustations on the sides of the craters. Almost all the sulphur of commerce in Europe, is procured from the craters of dormant volcanoes in the south of Italy, Sicily, and the Lipari Islands. When the combustion of sulphur in volcanoes takes place, where there is access to atmospheric air, it forms sulphurous acid gas, and sulphuric acid.

Carbon combined with hydrogen, forming bitumen, is found in volcanic rocks, and also in some basaltic or trap rocks. The volcanic tufa in the vicinity of Clermont, in France, contains so much bitumen, that in warm days it oozes out, and forms streams of bitumen resembling pitch, which is the more remarkable, as this tufa must have been erupted some thousand years. Bitumen has been observed oozing out of the lava of Ætna. The *moya* erupted from the volcanoes in the Andes, in aqueous or muddy eruptions, contains so much bitumen or carbon, as to be inflammable. As bitumen exists in many volcanic rocks, the black smoke which issues during an eruption may in some cases proceed from its combustion, though the smoke has generally been supposed to consist of minute volcanic sand, called ashes. Carbon also combines with hydrogen in a gaseous state, and forms carbureted hydrogen gas.

The hydrogen gas evolved from volcanoes, or from chasms in the earth during earthquakes, is generally combined with sulphur or carbon; it is probably formed by the decomposition of water, when it finds access to subterranean fire. Whether phosphorus be a product of volcanoes is unknown: its extreme imflammability prevents it from being discovered in a concrete form; but the dense white clouds, like bales of cotton, which sometimes cover Vesuvius, resemble the fumes produced by the combustion of phosphorus. Among the known products of volcanoes, only three are combustible at a moderate temperature;—sulphur, hydrogen, and carbon. It was at one time maintained by Sir H. Davy, that the earths and alkalies which form lavas, exist in the center of the globe in a metallic state, and take fire by the access of water. The property of the newly discovered metals to inflame instantly on the access of water, offers an easy explanation of the origin of volcanic fires, could we suppose that substances so extremely inflammable and oxidable, have remained for ages in a metallic state. This theory is now abandoned. There may, however, be processes going on in the vast laboratory of the globe, that separate the earths from oxygen, and prepare them for the support of volcanic fires, by which they are thrown upon the surface, and thus establish a communication between the internal and external parts of our planet.

The saline products of volcanoes are not numerous. The sulphurous vapor and sulphuric acid, formed by the combustion of sulphur during eruptions, act upon volcanic and other rocks, and produce different combinations, of which the most important are alum, sulphate of magnesia, sulphate of iron, or green copperas, and gypsum. Muriate of ammonia, or salammoniac, forms an incrustation on many lavas, soon after they cool: muriate of soda, or common salt, and muriate of copper and of iron, are found in the craters of volcanoes. Muriatic acid, in an uncombined state, occurs in some of the spongy lavas in Auvergne.

The *principal metallic substances* in volcanic rocks are iron and titanium; but ores of antimony, copper, and manganese, have sometimes been found in the craters of volcanoes. Tellurium, gold, and mercury, are also said to occur in some volcanic rocks. The island of Ischia, which is entirely volcanic, contains a mine of gold.

Iron, in the form of brilliant laminæ, called specular iron, occurs in the cavities and fissures of many lavas. Magnetic iron ore, and oxide of iron, with iron sand and titanium, form a constituent part of nearly all dark colored lavas or basalt.

The *earthy products* of volcanoes are either vitreous, or stony, or scoriaceous, or spongy, or in loose grains or in powder. Volcanic rocks are composed chiefly of felspar, and the dark colored mineral called augite; they contain also hornblende and grains of magnetic iron ore, with titanium and iron sand, and the mineral called olivine. Mica, leucite, iron pyrites, garnets, rubies, and zircon, are also found in some volcanic rocks. The different states of lava, whether vitreous, compact, or scoriaceous, depend on the different circumstances under which it has cooled.

Volcanic rocks, being principally composed of the two minerals, felspar and augite, very minutely intermixed, derive their principal characters from the prevalence of one or other of these minerals. Those lavas in which felspar greatly predominates, have generally a whitish or greyish color, and melt into a white glass. The lavas which contain a large portion of augite, have a dark color, and melt into a black glass. According to M. Cordier, all volcanic rocks that have flowed as lava, and which appear the most homogeneous, are composed of microscopic crystalline particles, belonging to a small number of minerals, particularly felspar, augite, olivine, and iron sand; and the same intermixture of minerals may be observed in all scoriaceous lava and in basalt. To the white or grey lava, composed principally of felspar, the French have given the name of *trachyte*, from its breaking with a rough surface.

Trachyte.—Common or stony trachyte has generally a whitish or greyish color, a dull earthy fracture, and is more or less fine grained; sometimes the grains are very minute, and it has then

a compact surface, and sometimes a glistening lustre, in which state it becomes pearl stone. Its hardness is variable; some of the trachytes near Clermont are spongy, and almost friable. Trachyte melts into a greyish glass; it generally contains imbedded crystals of vitreous felspar. Acicular or needle shaped crystals of hornblende, hexagonal crystals of mica, and grains of iron sand, and laminæ of specular iron ore, occur in trachyte. Augite is seldom found in the trachyte of Europe, though it is common in the trachytes of the Andes.

Trachyte occurs in the Lipari Islands in a perfectly vitreous state, forming obsidian or volcanic glass, which is sometimes colorless and sometimes black; the black variety, however, forms a white glass when melted. The coloring matter, being fugitive, is probably bitumen: in this respect it differs from obsidian formed from dark lava or basalt: the latter melts into a black glass.

Pumice.—Pumice appears to have been formed from trachyte, exposed to an intense heat, which has reduced it to a fibrous mass. The island of Lipari contains a mountain entirely formed of white pumice: when seen at a distance, it excites the idea, that it is covered with snow from the summit to the foot. Almost all the pumice stone employed in commerce is brought from this immense mine. The mountain is not one compact mass, but is composed of balls or globes of pumice aggregated together, but without adhesion. From hence Spallanzani infers, that the pumice was thrown out of a volcano in a state of fusion, and took a globose form in the air. Some of these balls of pumice do not exceed the size of a nut; others are a foot or more in diameter. Many of these pumices are so compact, that no pores or filaments are visible to the eye; when viewed with a lens, they appear like an accumulation of small flakes of ice. Though apparently compact, they swim on water. Other pumices contain pores and cavities, and are composed of shining white filaments. By a long-continued heat, pumice-stone melts into a vitreous semi-transparent mass, in which a number of small crystals of white felspar are seen. Black or dark-colored pumice is more uncommon. Humboldt says, he has seen black pumice in which augite and hornblende may be recognized; he is inclined to think that such substances owe their origin to basaltic lavas, which have assumed a capillary or fibrous form by intense heat.

Immense quantities of pumice are sometimes thrown up by submarine volcanoes. It has been seen floating upon the sea over a space of three hundred miles, at a great distance from any known volcano;* from hence it may be inferred, that submarine volcanoes sometimes break out at such vast depths under the ocean,

---

* It is probable that the strata of Neapolitan tufa, which contain marine shells, were deposited by submarine volcanoes.

that none of their products reach the surface, except such as are lighter than water.

Obsidian, or volcanic glass, so nearly resembles lumps of black glass, that they can scarcely be distinguished by the unpracticed observer. Its broken surface is smooth, conchoidal, and shining: the most common color of obsidian is a velvet black. The thinner pieces are translucent. It is harder than glass, and strikes fire with steel. It is common in the neighborhood of volcanoes, and in some basaltic formations. The obsidian accompanying basalt contains a large portion of augite, and melts into a black glass as before mentioned; in other respects, its mineral characters are the same as those of obsidian from trachyte. In the island of Lipari, the mountain de la Castagna, according to Spallanzani, is wholly composed of volcanic glass, which appears to have flowed in successive currents, like streams of water, falling with a rapid descent, and suddenly congealed. This glass is sometimes compact, and sometimes porous and spongy.

On the elevated plain which surrounds the conical peak of Teneriffe, there are masses of obsidian, which graduates into pitchstone, containing crystals of white felspar. On the south-west side of the peak, there is a stream of vitreous lava or obsidian, several miles in length. Col. Imrie describes a current of lava in the island of Felicuda, intermixed with obsidian, which had been flowing with it, and now forms part of the congealed stream. "In some parts the obsidian is seen losing its brilliancy, and passing into granular lava, which becomes similar in color, fracture, and texture, to the other parts of the stream. Where the obsidian appears in a state of perfect glass, it is very near to where it has been first ejected from the side of the crater, and in a situation where it must have undergone a rapid cooling. In some parts of these congealed streams, I could trace a transition of the obsidian into pumice. In these places, the obsidian contained scattered air globules, which were almost always lengthened in the direction of the stream. These globules gradually augmented in number, until the whole substance became a light, fragile, and frothy pumice."* Volcanic glass is found in the crater of Vulcano, one of the Æolian islands, and may be seen forming there at the present time.

Volcanic Tufa.—Owing to the facility with which trachyte breaks down, it forms beds of conglomerate intermixed with scoriæ and pumice. The more finely comminuted parts of trachyte, intermixed with earthy matter, form beds of tufa. These beds of conglomerate and tufa frequently environ trachytic mountains, and hide from the view of the geologist their connection with the subjacent rocks.

---

* Memoirs of the Wernerian Society, Vol. II, p. 47.

When trachyte becomes compact and hard, and acquires a laminar or slaty structure, it passes into clinkstone or pholonite, so called on account of its yielding a metallic sound when struck. (See Chap. X, where it is observed, that dark lava or basalt also passes into clinkstone.) Thus it appears, that both the light-colored lava, or trachyte, and the dark-colored lava, or basalt, according to the different degrees of heat to which they have been subjected, or the different circumstances under which they have cooled, form volcanic glass, clinkstone, or pumice; and the only difference to be observed in the minerals formed from the trachyte or the basalt, is a difference of color in the minerals themselves, or in the glass which they yield when melted. Black pumice from basalt is however very rare.* Basaltic dykes, and the overlying rocks of porphyry, trap, and basalt, described in Chapter X, ought, I am persuaded, to be classed with ancient volcanic formations, but their igneous origin is not yet universally admitted, and it is desirable to separate theoretical views from a description of facts. This, however, cannot always be done: circumstances which indicate the mode of rock formations, will deservedly force themselves on our attention, and in stating them fairly, and the inferences which may be drawn from them, we relieve geology from much of its dryness, and stimulate succeeding observers to a strict investigation of nature.

Dark-colored recent lava does not differ essentially from basalt: it is generally more porous. Probably the compact state of basalt was the result of refrigeration under pressure; it may, however, be frequently observed in Auvergne, passing into the state of scoriaceous lava. Some of the recent lavas from Vesuvius are compact, and have a glistening lustre, but they are more commonly porous. In some volcanic eruptions, lava appears to have acquired the most perfect fluidity. According to Professor Bottis, who

* According to the microscopic and mechanical analysis of light-colored and dark lavas, by M. Cordier, (whether compact or scoriaceous,) it appears that the stony lavas which melt into a white glass, contain ninety per cent. of felspar. Those lavas which melt into a bottle-green glass or enamel, contain only from fifty-five to seventy per cent. of felspar; such are the greenish, greyish, or dark-colored basalt. On a microscopic examination of dark lava or basalt, it appears to consist of minute crystalline grains. The whitish grains belong chiefly to felspar, but in the lava from Vesuvius, to leucite; a small proportion of these grains are chrysolite. The yellowish or greenish grains belong to augite and hornblende: those of augite are rounded and irregular, with a vitreous fracture and splendent lustre. The grains of hornblende are long, and assume a prismatic form; they present indications of a laminar structure, and have little lustre. The perfectly black grains are iron sand, containing iron combined with titanium; the grains of iron ore (*fer origiste*,) may be known by yielding a red powder when pulverized. Volcanic glass, volcanic scoriæ, and volcanic tufa, are all composed of the same minerals as the most compact lava, and all the most homogeneous dark volcanic rocks are composed of minute microscopic grains, which are chiefly felspar and augite, with a small proportion of olivine and iron sand. M. Cordier informed the author, that the microscopic examination of lava was much facilitated, by steeping the piece to be examined in dilute muriatic acid.

was an eye-witness of the eruption of Vesuvius in 1776, the lava spouted from three small apertures, precisely like water, forming beautiful fountains of fire, which described curves of different dimensions as they fell. In the same year, a current of lava from the summit of Vesuvius flowed with the velocity of a mile and a half in fourteen minutes: it struck upon the lava of 1771, and rebounded into the air, congealing in figures of various shapes. The length of time which currents of lava retain their heat is truly remarkable: the current which flowed from Ætna in 1669 is two miles in breadth, fifteen miles in length, and two hundred feet in depth; it retains a portion of its heat to the present day. Ferrara says, when this lava was perforated at Catania in 1809, flames broke out; and it continued to smoke at the surface after rain, at the beginning of the present century, or 130 years after its eruption.

Stones of enormous size are frequently projected from the craters of volcanoes; but the quantity of matter which they throw out in the state of scoriæ, sand and powder, often exceeds that erupted in the state of lava, and is spread over distant countries. By the percolation of water, the loose materials become agglutinated, and form beds of volcanic breccia, and tufa. Sometimes the tufa is sufficiently solid to be used for building-stone; the Roman pepperino is a volcanic tufa. Pozzolana consists of minute particles of scoriæ, which have been partially decomposed: mixed with lime, it makes a water-setting cement.

Some volcanic rocks decompose rapidly, and form productive soils; others resist the process of decomposition so effectually, that, after the lapse of many centuries, they present all the freshness of the most recent lavas.

Age of Volcanic Rocks.—Nothing precise can be determined with respect to the relative age of volcanic rocks, except in those districts where they occur together, one covering the other. Humboldt, who has attempted to trace the different ages of volcanic formations, observes, that there are trachytes, clink-stones, and basalts, of different ages; but in proportion as we advance towards the more recent volcanic formations, they appear isolated, superadded, and strangers to the soil in which they are found. The lavas from existing volcanoes vary at different periods of their eruptions: we may, therefore, well conceive, that the volcanic masses which, during thousands of years, have been progressively raised to the surface, under very different circumstances of pressure and refrigeration, should present striking contrasts and analogies of structure and composition.

CHAPTER XX.

ON THE REPOSITORIES OF METALLIC ORES.

Metallic Matter disseminated through Rocks.—Masses of Metallic Ore.—Metallic Beds.—Metallic Veins.—Rake Veins.—Flat Veins.—Accumulated Veins.—Cross Courses.—The remarkable Structure of the Botallack Mine worked under the Sea.—On the formation of Metallic Ores.—Remarkable Phenomena in Mines.—Stream Works.—Gold disseminated in the Sand of Rivers in Africa, and North and South America.—Rocks in which certain Metallic Ores are found.—Observations on Electro-Chemical Experiments that appear to elucidate the Formation of Metallic Ores.

The rocks and strata, described in the preceding chapters, are composed of earthy minerals, sometimes combined with a portion of metallic matter, which in such instances may be regarded as a constituent part of rocks. The mineral substances to be described in the present chapter, as forming beds, or veins, or irregular masses, or grains imbedded in other rocks, consist of metallic matter either pure, or in combination with sulphur, oxygen, or acids.

The difference of external character between a pure metal and an earth is so great, that we find some difficulty, at first, in conceiving how metallic matter can form beds interstratified with earthy rocks; but the discoveries of modern chemistry have shown, that metallic and earthy minerals are closely allied. Nothing can appear more essentially different than a piece of polished iron and a piece of marble or slate; yet if iron be exposed to the action of air and water, it is converted into rust, and in this state is known as ochre; and between ochre and powdered stone there is little difference of external character; nor would any one unacquainted with chemistry suspect that ochre was a metallic mineral. The ochre can, however, be easily reconverted into metallic iron: but to convert the earths into a metallic substance is a difficult process,—yet it has been effected; and it is further proved, that both earths and alkalies are metallic substances combined with oxygen. The metallic nature of the earths being ascertained, we can no longer be surprised that metallic minerals should be found intermixed with earthy minerals in rocks. Iron is found combined with earths in almost all rocks that are not white; and to the presence of iron they generally owe their color, whether red, brown, or black.

The other metals rarely occur chemically combined with rocks or strata, but are found either disseminated in grains or irregular pieces, or forming beds between earthy strata, or filling veins that intersect rocks in different directions.

Except gold and platina, metals are rarely found pure, but are generally combined either with sulphur, oxygen, or acids; in this state they are called *ores.* When the metals occur pure, they are called *native metals:* thus we have native gold, native iron, &c.

Metallic ores and native metals are sometimes disseminated in grains through rocks, and when they are abundant, the whole mass of the rock is worked as a mine; but this is seldom the case. Tinstone, or the oxide of tin, is sometimes disseminated in grains in granitic rocks in Cornwall, but it is generally in the vicinity of a vein of tin ore, that disseminated grains of tinstone are found in the rock. At Weal Duchy mine, near Callington, silver ore is obtained, both from a vein which intersects the hill, and from the rock itself, at a considerable distance from the vein. From a section of the mine shown me by the proprietor, it appears that in the rock, which is white killas (a silvery clay slate,) the ore is disseminated in various parts, or is collected in bunches. The silver is found native in filaments, or in the state of vitreous silver ore, black silver, and ruby silver. Gold frequently occurs in grains, disseminated through solid rocks, or in the sands of rivers. Considerable masses of metallic ore are sometimes found in rocks, particularly of iron ore; but these masses are generally formed by the meeting of numerous veins, or are parts of metallic beds, that are greatly enlarged:—they will be described with beds and veins.

Metallic Beds.—Some metallic ores occur, taking the form of regular strata, in the secondary rocks, or of beds in transition and primary rocks. Ironstone in thin strata, alternates with coal, coal-shale, and sandstone, and has been described with the coal strata in Chap. VIII.

Iron ore often forms beds of considerable thickness, interposed between rocks of gneiss, mica slate, and slate. Metallic ores in beds or strata, may be regarded as constituent parts of the rocks in which they occur, and must be contemporaneous with them; the metallic and the earthy minerals have been deposited at the same time, and have probably been separated by chemical affinity, during the process of consolidation. Sometimes, as before stated, the metallic matter is intermixed with beds of slate or other rocks, in such abundance, that the whole bed is worked as a metallic ore. When a bed of metallic matter swells out irregularly to a considerable thickness, it forms masses of ore, which in some instances attain the magnitude of small mountains,—such are the mountains of iron ore in Sweden and Norway. Metallic beds are, however, of limited extent; they seldom traverse a whole mountain or mountain range, but they gradually or suddenly become narrow, and terminate, or, in the miners' language, *wedge out.* There are few known beds of metallic ores in England; the principal repositories of metallic matter are in veins. I have, however, ascertained, that the copper mines formerly wrought in

the transition rocks of Cumberland, were beds of copper pyrites, interposed between the beds of the mountains in which they were found, and not intersecting them like veins. The beds of rock being highly inclined, the thin metallic beds between them have been mistaken for veins. I believe that several metallic repositories in other countries, which have been described as veins, are in reality beds; the distinction between beds and veins not being well understood, they are both called veins by working miners. The manganese mines at Doddiscombe Leigh, in Devonshire, are irregular beds of oxide of manganese in red sandstone. The iron mine at Dannemora, in Sweden, is an enormous bed, which has swelled out to the thickness of one hundred and eighty feet of nearly compact ore. Mercury has been found disseminated in beds of clay and sandstone. Black oxide of cobalt occurs in beds of sandstone at Alderly Edge, in Cheshire.

Metallic Veins.—Perhaps the reader may obtain a clearer notion of a metallic vein, by first imagining a crack or fissure in the earth, a foot or more in width, and extending east and west on the surface, many hundred yards. Suppose the crack or fissure to descend to an unknown depth, not in a perpendicular direction, but sloping a little to the north or south. Now let us again suppose each side of the fissure to become coated with mineral matter, of a different kind from the rocks in which the fissure is made, and then the whole fissure to be filled by successive layers of various metallic and mineral substances; we shall thus have a type of a metallic vein. Its course from east to west is called its *direction*, and the dip from the perpendicular line of descent is called the *hading* of the vein, in miners' language. Thus it is said to *hade* or dip to the south or north, &c. Now it is obvious that if the direction of the vein were changed, or its width increased or diminished, and the hade or dip were increased or diminished also, we should still have all the essential conditions of a metallic vein remaining. Let us now proceed to describe existing metallic veins. They appear to have been originally fissures cutting through different beds of rock, that have been subsequently filled with metallic ores, intermixed with other mineral matter, of a different nature from that of the rock which is intersected. Metallic veins are, therefore, considered to be of posterior formation to the rocks in which they are found: and where a vein cuts through different rocks, it is evident that its formation must have been more recent than that of the rocks which it intersects; but where a vein is found only in one bed of rock, the fissure may have been formed and filled at the period when the rock was consolidated. Metallic veins are principally found in primary and transition rocks; they are often separated from the rocks they intersect, by a thin wall or lining of mineral substances distinct from the rock, and sometimes also by a layer of clay on each side of the vein. The same substance which forms the outer coat of the vein, is also

frequently intermixed with the ore, or forms layers alternating with it: this is called the matrix, gangue, or veinstone. It appears as if the ore and the veinstone had been formed over each other, on the sides of the vein, at different times, till they met and filled up the fissure.

Sometimes the ore extends in a compact mass from one side of the vein to the other; but not unfrequently there are hollow spaces in veins, called *druses*, which are lined with crystals; in these cavities, the most beautiful and regular crystalline forms are obtained. Metallic veins often divide and unite again, and sometimes they separate into a number of smaller branches, called *strings*. A general idea of the different modes in which metallic veins intersect rocks, and are sometimes intersected by each other, is represented in the annexed cut.

A, A, represents a metallic vein which at B, divides into two branches, that unite again lower down, and appear to terminate in a number of branches or strings, too poor to be profitably worked. In some cases these branches lead to a continuation of the large vein.

C, is a vein descending in a different direction. In this vein the ore and matrix in some parts contract to a narrow string, and afterwards expand to a considerable width; such contractions and expansions are of frequent occurrence in veins. At D, D, the vein C, is cut through and displaced by the vein A. Where this separation takes place, it is evident, as was first observed by Mr. Price, in his *Mineralogia Cornubiensis*, that the vein C, which is cut through, is more ancient than the vein A, which intersects it. In plate 7, fig. 4, a small vein is represented as cut into three parts by the larger veins *a* and *b*.

To what depth metallic veins descend, is not known; nor is it ascertained, whether they generally grow wider or narrower in their descent. The opinions of miners on this subject are so various, that it may fairly be inferred, that veins differ, in this respect, in different situations. No instances, I believe, have occurred, of a vein being absolutely worked out in depth, though it often grows too poor to repay the labor of working deeper: more frequently, the further descent of the miner is stopped by the difficulty or expense of removing the water. Veins are seldom rich in ore near the surface, but increase in richness as they descend, and at greater depths become poorer again. When Pryce wrote the "Mineralogy of Cornwall," it was believed that the richest state of a mine for copper in that county, was from eighty to one hundred yards deep; and for tin, from forty to one hundred and twenty yards. This account by no means agrees with the present state of the Cornish mines. Copper and tin are procured in considerable quantities at the depth of four hundred and fifty six yards in the Dolcoath mine. The Ecton copper mine, in Staffordshire, is now worked at the depth of four hundred and seventy two yards: it is the deepest mine in England. The deepest mine that has been worked in Europe, or in any part of the world, is one at Truttenberg, in Bohemia, which is one thousand yards below the surface.

Metallic veins frequently contain different ores at various depths. Iron ore, copper ore, cobalt ore, and silver ore, succeed each other in some of the mines in Saxony.

In France, there are mines which contain copper ore in the lowest part, silver ore above, and over that, iron ore.

In Cornwall, blende, a sulphuret of zinc, frequently abounds in the upper part of veins, that become rich in copper as they descend; the blende rarely continuing to any considerable depth. In the same district, tin is also commonly found at a small depth, in veins which afterwards prove rich in copper. "Among other instances that might be quoted, are the two deep extensive copper mines, called Huel Unity and Cook's Kitchen, both of which were worked for tin at first. In both, the tin was soon extracted; but it should be noted, as an uncommon circumstance, that in the latter mine, after working to the depth of one hundred and eighty fathoms, first through tin, and afterwards through copper, tin was found again, and has continued down to its present depth of two hundred and ten fathoms from the surface. It ought, however, to be added, that some portion of tin was found in different parts of the vein, which may therefore be said to have prevailed more or less from the surface to the present workings."*

The thickness of veins, and the quantity and quality of the ore they contain, vary in every mine. Some veins are only a

* Transactions of the Geological Society, Vol. II.

few inches wide; others are several feet, and sometimes several yards, in width. Veins are often narrow in one part, and swell out in another. The vein at the Dolcoath mine in Cornwall, varies from two or three feet to forty feet; and in some places it contracts to little more than six inches. The veinstone is quartz, in which are imbedded masses, called bunches of copper pyrites, consisting of copper combined with sulphur and iron.

Beside perpendicular veins, sometimes called rake veins, there are other mineral repositories, called flat veins, or flat works, and pipe veins. In some instances, a rake vein declines from its regular inclination, and has taken the direction of the beds of rock running between them for a greater or less extent, and then resumes its former inclination. In other instances, the cavities between beds or strata are filled with metallic ores, lying between an upper and lower stratum, like a seam of coal, and are subject to similar dislocations: but these are not regular strata; they may frequently be traced to a perpendicular or rake vein, from which they appear to be lateral expansions; see Plate VII, fig. 2, in which the regular vein is seen descending, and the flat vein branching off on each side near the bottom.

There is generally what is called a rider, or mass of mineral matter, between the ore of very strong rake veins, and that in the flat veins, at the place of junction. The flat veins that run parallel between the strata, frequently open into large cavities filled with ore and veinstone; these cavities close again by the contracting, or what the miners call twitching of the sides, by which the ore is nearly or totally excluded.

The blue john, or fluor spar mine, near Castleton, is of this kind. The vein which contains this spar, is separated from the limestone rock by a lining of cawk or sulphate of barytes, and by a thin layer of unctuous clay; it swells out into large cavities, which contract again, and entirely exclude the ore, leaving nothing but the lining of the vein to conduct the miner to another repository of the spar. The crystallizations and mineral incrustations on the roof and sides of the natural caverns, which are passed through in this mine, far exceed in beauty those of any other cavern in England; and were the descriptions of the Grotto of Antiparos translated into the simple language of truth, I am inclined to believe it would be found inferior in magnificence, and splendor of mineral decoration, to the natural caverns in the fluor mine. This mine is rarely visited by travellers: the descent is safe, but, the roof being low in some parts, it is rather difficult of access.

The pipe vein may be described as a tubular mass of ore and veinstone, generally descending in the direction of the beds, and widening and contracting in its course. In reality, the pipe vein is a variety of the flat vein, having the sides closed or twitched

in, so as to form a tube or cavity of irregular shape, and of very limited extent along the line of bearing, but descending to a great depth.

Sometimes one vein crosses another without changing the direction; and if they both have nearly the same inclination, or dip nearly to the same point of the compass, they are generally richer near their junction, as at *b*, Plate VII, fig. 4. When a number of veins cross each other at one place, they sometimes form a cone or mass of ore, of vast size, widening as it descends. Such are called accumulated veins. They occur in the metalliferous limestone of Durham and Northumberland. When one vein crosses another in an opposite direction, they often are found poorer in ore near the junction. Fig. 3 shows a ground plan of the vein *b b*, cut through nearly at right angles by another vein or cross course: in such instances, the vein *b b* becomes poorer; but this is not universally the case. In the same figure, the veins *c c* are cut through obliquely.

The direction of rake veins is not very regular. In England, the principal veins generally run nearly east and west, and northeast and southwest; but have frequently undulations and deviations from a straight line: the most powerful veins are more regular in their course than smaller ones. Where two veins in the same district have the same direction, or run parallel, it is observed that their contents are similar; but where they run in different directions, the contents vary. Molina, in his interesting History of Chili, mentions a vein of silver at Uspalata, in the Andes, which is nine feet in thickness throughout its whole extent, and has been traced ninety miles. Smaller veins branch off from each side of it, and penetrate the neighboring mountains to the distance of thirty miles. It is believed that this vein stretches to the distance of three hundred miles. A vein, called the Tidswell Rake, in Derbyshire, extends some miles east and west; it is worked from the surface, and may be seen near the roadside, between Great Hucklow and Tidswell. I was informed in Cornwall, that no vein in that county had been traced in length more than two miles; nor had any vein been worked out in depth. The common width of the veins is from one to two feet, but sometimes the width exceeds thirty feet.

In Cornwall and Devonshire, and in the mines of Northumberland and Durham, the principal metallic veins range nearly east and west. In the former counties they are called *lodes*, in the latter, *right-running veins*. The north and south veins which intersect them are called cross courses: these are seldom productive of ore. Plate VII, fig. 3, the veins *b b c c* are represented as cut through by a cross course. It must be borne in mind that this is a ground plan. The thin cross courses filled with clay are called *fluan*. I was informed by an intelligent

proprietor of mines in Cornwall, that these thin cross courses invariably displace the veins, and hold up the water on one side of the vein; but it is most worthy of notice, that a vein which is rich in ore on one side of the fluan, will be poor on the other. Query, *Is this connected with the fluan holding up the water?* In Cornwall displacement by cross courses is only a few inches in some veins, in others it is several fathoms. On Allston Moor, in Cumberland, a large cross course, called Old Carr's Cross Vein, cuts through two veins called Goodham Gill Vein, and Grass Field Hill Vein, and has thrown them aside about fifteen or twenty fathoms. When the cross course intersects the east and west veins at right angles, the displacement is generally less, than when it strikes it in an oblique direction. This effect will be more clearly understood by referring to Plate VII, fig. 3.

In Northumberland and Durham, cross courses contain ore, near their junction with powerful veins. In Cornwall, ores of silver and cobalt have been found in some of the cross courses: and at the Botallack mine, north of the Land's End, a powerful cross course, running north and south, is made rich by the junction of east veins, which resemble small rivulets, opening into a river. Their position will be better understood by referring to Plate VII, fig. 6. The direction of the cross course or great vein, running north and south, is represented by the letters N, S, the direction of the small veins, rich in ore, which open into it, are represented by *e e e*. The cross course is rich in ore to the distance of twenty or thirty fathoms, on each side of its junction with a vein; but no veins are found branching from the west side of the cross course. The cross course is worked in those parts, where it is rendered rich by the junction with veins; the small veins are also worked for ore and are very productive. The rock is what is called a free or soft killas, near the great cross course or vein; but further from it, it becomes a hard blue elvan *(flinty slate.)* The width of the vein varies from nine to twelve feet. It contains grey copper ore of a rich quality. Sometimes the sides of the vein are copper ore, and the middle is tin ore, as represented Plate VII, fig. 7, *c c*, which is a vertical section of part of the vein; fig. 6, is a horizontal section of the cross course and veins. The master of the mine furnished me with the above particulars; and under his direction, I made, on the spot, the two rough sections, which will serve to convey a better notion of this singular metallic repository, than can be obtained by a verbal description.

Nor should it be omitted, that the entrance of this mine is at the foot of a precipice more than 200 feet in height, on the border of the Atlantic Ocean, and the workings of the mine, extend two hundred and thirty yards under the sea. From this submarine recess, I saw rise up one of the best formed and noblest looking men I ever beheld,—a perfect model for the Apollo of a sculptor.

Particular metallic ores are peculiar to certain rocks. Thus, tin ore occurs in granite, and some kinds of slate, but has never been found in limestone. Certain ores are not unfrequently associated together: thus, lead and zinc often occur in the same vein, but in different proportions. The same metal in various combinations is often found in one vein: thus, native copper, sulphuret of copper, carbonate of copper or malachite, sulphate of copper or blue vitriol, and copper combined with lead and iron, frequently occur together in the same mine.

Galena, a sulphuret of lead, is often associated with white lead ore, or carbonate of lead. The latter though a rich ore, containing seventy per cent. of lead has no metallic appearance, and was mistaken for cawk, and thrown away, by the miners in Derbyshire, until the year 1803 or 1804. The mines of that county have been worked ever since the time of the Emperor Adrian, and the quantity of ore which has been wasted during that period must have been immense.*

In what manner metallic veins were filled with ore has greatly divided the opinions of geologists. Dr. Hutton supposes that both dykes and veins were filled, with their contents in a state of fusion, by injection from below, the expansive force of the melted matter having cracked the surface, and opened a passage for its reception. (See Chap. X.) That many dykes were so formed I think probable, from circumstances previously stated. Other dykes appear to have been open fissures, filled by materials washed from the surface, and contain rounded stones, and sometimes undecayed vegetable matter. From a dyke of clay in a coal mine in Yorkshire, two hundred and fifteen feet deep, I have drawn out long vegetable fibers, apparently roots, the woody part of which was unchanged, and burned like the roots of common weeds.

Werner supposes all veins and dykes were first produced by the shrinking of the materials, of which mountains are composed; and that metallic veins have been filled from above, by the ores in a state of solution.† This theory has been advanced with much confidence, and warmly supported by many geologists: but I have no hesitation in asserting, that it is demonstratively repugnant to facts: indeed, the implicit credit which has been given to Werner's dogmas on this subject, is one, among numer-

* In 1810 few of the working miners could distinguish compact white lead ore, from cawk or sulphate of barytes; their specific gravity and appearance are not very different. The following test is of easy application, and will serve to discover the presence of lead:—If a small quantity of flowers of sulphur, mixed with a little potash or soda, be melted on the point of a knife, in a candle, and applied to the moistened surface of the stone, it will make a black spot, if the mineral contains white lead ore.

† The round pebbles which are sometimes found in veins, have been cited to prove that veins were filled from above: they were probably introduced by subterranean currents.

ous instances, of men of distinguished talents resigning their judgment to authority, and supporting the most absurd propositions, when conformable to their favorite hypothesis. If veins were filled by metallic solutions from above, these solutions must have covered the highest mountains over the whole earth; and, instead of finding metallic ores in the present confined repositories, they would fill all the cavities and valleys in every part of the world. As this theory supposes likewise, that veins were formed at different times, a number of these metallic solutions would succeed each other: we should find regular strata of ore in all primary and transition rocks, and the quantity formed by these deep seas of metallic matter, would be inconceivably great.

This theory is decidedly invalidated by the following facts. When a metallic vein passes through different kinds of rock, it is generally observed that the quality of the ore varies with that of the rock through which it passes: even some beds of the same rock are more productive than others, and are called by miners *bearing measures.* This is the case in Durham, Derbyshire, Cornwall, and probably in every mining district, in England and Wales.

Not only does the variation in the nature of the rock occasion a change in the quantity or quality of the ore, but the mineral substance or matrix which accompanies ores, generally varies in different kinds of rock. Quartz and barytes are more frequently the matrix in granite and slate rocks, than calcareous spar; in calcareous mountains, quartz is rarely the prevailing matrix. In the counties of Durham and Northumberland, veins pass through siliceous sandstone, argillaceous shale and limestone. (See Plate VII, fig. 2.) The ore is more abundant in the limestone than in the sandstone, and in the shale, provincially called *plate,* ore very rarely, if ever, occurs. In one mine at Welhope the matrix of the vein, as it passes through the sandstone, is cawk or the sulphate of barytes; but when it enters the limestone, it changes to carbonate of barytes in balls, having a radiated diverging structure. What is still more deserving of notice, when the rock on one side of a vein is thrown up or down considerably, so as to bring a stratum of limestone opposite a stratum of sandstone, or when what are called the walls or cheeks of the vein are of two different kinds of stone (see plate VII, fig. 5,) the vein is never so productive in ore, as when both sides of the vein are of the same kind. In the above figure, different strata are opposite to each other, except where the strata are of great thickness: thus, parts of the lower bed of limestone, *a a,* form the wall on each side of the vein, and in such situations it is rich in ore; but the upper part of the bed, *a,* is brought opposite to a bed of sandstone, *b,* on the left; and in this part of the vein it will become poorer, and the same will be the case when the vein passes through the upper

strata; in some it will contain no metallic ore. This fact alone seems sufficient to invalidate the theory of Werner, that veins were filled with metallic solutions, poured in from the upper part. Had this been the case, the nature of the rock could have made no difference in the quality or quantity of the ore.

Werner, in his "Treatise of Veins," states one instance, as if it were extraordinary, of the ore changing its quality, as the vein passed through different rocks; and is inclined to admit, that elective affinity for the rock may have contributed to the effect. The circumstance, so far from being extraordinary, is of common occurrence, and known to all working miners. The entire cessation of the ore in one part of a rock, and its re-appearance below, are still more striking.

In Derbyshire, the beds of metalliferous limestone are separated by beds of basaltic rock, called toadstone. When a vein of lead is worked through the first limestone down to the toadstone, it ceases to contain any ore, and often entirely disappears: on sinking through the toadstone to the second limestone, the ore is found again, but is cut off by a lower bed of toadstone, under which it appears again in the third limestone. In strong veins, particles of lead occur in the toadstone, but in very small quantities.

If mineral veins were filled from above by metallic solutions, it is impossible to conceive that the nature of the rock should change the quality of the ore; much less could the ore disappear in one stratum, and appear again in a stratum below it. Nor could the vein be filled by matter ejected or sublimed from below; for in either case it would be equally impossible to explain why the ore disappears in the toadstone, though the vein is continued through it. See Plate IV, fig. 5, where *b b b* are three beds of limestone divided by beds of toadstone, *e e*, and covered by sandstone. When the vein descends to the first bed of toadstone, *e*, the ore disappears; but on sinking through to the second bed of limestone, it is found again: it disappears a second time at the next bed of toadstone, and reappears in the lower limestone, 3. Another vein, *a a*, is supposed to penetrate the beds of toadstone, *e e*, but contains little ore where it passes through them. The upper part of the vein, *a*, is represented as penetrating the superincumbent sandstone, which is sometimes the case; in this upper part of the vein, the most curious productions of the Odin mine, near Castleton, are discovered.* Such facts prove that these veins

* The fact of metallic veins being entirely cut off by the beds of toadstone, has recently been doubted; it is supposed that the vein is continued through the toadstone, though it contains no ore: but the fact of veins being cut off by the seams of clay, (called *way boards*,) if it could be established, would lead to the same conclusion as the separation of the vein by toadstone. My late visits to Derbyshire have convinced me more fully that Mr. Farey was too hasty in forming his opinions, and that he did not always select his information from the best sources. Neither the beds of clay nor toadstone may contain ore, and yet the vein may pass

were not filled from above. Professor Jameson has conjectured, that the beds of toadstone and limestone in Derbyshire, with the metallic veins, were all cotemporaneous, and that the toadstone crossed through the veins at the time of their formation; but the different organic remains in the upper and lower beds of limestone, preclude the possibility of their having been formed at the same time. The zoophytes in the lower bed of rock could not be living and co-existent with those in the upper, nor with the vegetable remains occasionally found in the sandstone which frequently covers the whole, and into which the veins sometimes shoot. Cuvier has well observed, that the existence of different organic remains offers incontestible proofs, that the upper and lower strata in which they were found, were formed in succession. As a farther proof of the influence which the position of the rock has upon the vein which intersects it, the miners both in Wales and Derbyshire maintain, that wherever there is a depression in the strata, and they dip on both sides towards the vein, (see Plate VII, fig. 9,) in such situations the richest veins occur.

If metallic matter were not poured in from above, nor ejected from below, in what manner did it come into the vein? The state of chemical science, and the facts at present known, are too limited to furnish a solution to this interesting question. There are, however, certain indications which may serve as a clue to future discovery.

The variation of the mineral products in veins, as they pass through different strata, seems to prove, that the strata were efficient causes in producing this variation.

The discovery of the metallic nature of the very earths of which rocks are composed, and the probability that the metals themselves are compound substances of which hydrogen forms a part, open new views respecting the formation of metallic matter by natural processes, which may be within the reach of human power to develop, if not to imitate.

Perhaps metallic matter was diffused through different rocks according to their elective affinity, and separated from them by voltaic electricity, the different sides of the vein possessing different states of electricity; or the strata may act like a series of plates in the voltaic pile, separating and secreting metallic matter from its different combinations. Some of the metals and other substances found in veins, are capable of solution in hydrogen gas, and perhaps all of them may be so by natural processes; in

---

through them, but, being unproductive, it is not noticed. In some instances, the beds of toadstone may have been protruded between the beds of limestone, after the formation of metallic veins, as Mr. Whitehurst originally maintained.

*this state they may have penetrated the vein, and deposited their contents.**

If metallic matter be now forming in mines, the process of its formation is extremely slow; but there are circumstances which appear to prove, that it may in some instances be perceived. M. Trebra, director of the mines in Hanover, informed a gentleman of my acquaintance, that he had seen a leather thong suspended from the roof of a mine coated with silver ore: he had also observed native silver, and vitreous silver ore, coating the wooden supports left in a mine called Dreyweiber, in the district of Marienburgh, which had been under water two hundred years, and was opened in 1777.

M. Trebra was led to infer from his own observations on mines, that metallic ores are formed by mineral exhalations, or were once in a gaseous state. Mr. Westgarth Forster, a practical miner in Northumberland, states, that at Wolfclough mine, in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the walls, more than two inches in length.

These and other phenomena observable in mines, may convince us that there are processes going on at present in the great laboratory of the earth, and perhaps there are analogous processes taking place in the atmosphere, which may throw some light on these hidden operations of nature. The formation of saline matter on the surface of walls, is a fact which merits more attention than it has hitherto received. Dr. Kidd, of Oxford, has published some very ingenious observations and experiments, on the spontaneous production of nitre on limestone, which may lead to more important results, than the learned Professor appears to have anticipated. These experiments show, that neither the alkali, nor the acid exists previously in the stone; nor do they exist ready formed in the moisture of the atmosphere, dry frosty weather being particularly favorable to the rapid production of nitre, and moist weather the contrary.

When a portion of the wall was protected from access to the atmosphere by glass, which projected a little distance from the surface, the formation of nitre went on for a certain time, and then ceased. The saline crystals were better defined, and longer than on the other parts of the wall. When the wall was coated with paint, crystals of nitre were even formed on the paint. The formation of carbonate of lead on the walls of the mine at Wolfclough, may be analogous to the formation of nitre, and, in both

* The part printed in italics appeared in the first edition of this work, 1813, p. 227. I scarcely expected that the opinions then advanced, would in little more than twenty years afterwards, be so strongly confirmed by direct experiments, as they have been by those of Mr. Fox and Mr. Crosse.—See Observations at the end of the present chapter.

instances, the surface of the wall, and of the atmosphere, may perhaps be considered as two galvanic plates in action, decomposing and recompounding the elements of metallic or saline matter from the atmosphere, or the gaseous fluids with which it is intermixed. The base of nitre (potassium) is known to be a metal; and could we seize nature in the act of producing a fixed alkali from more simple elements, we might compel her to reveal the process, by which she prepares her metallic treasures in the deep recesses of the earth. Nor can the discovery be very remote; for we are already acquainted with the composition of the volatile alkali, and are thereby enabled successfully to imitate nature in its formation.

When the matrix, or the substance which principally fills veins, is a soft unctuous clay, masses and particles of ore are often disseminated through it, varying in size from a pea to that of a large gourd, and are sometimes even of many tons' weight. Masses of veinstone are also imbedded in the same manner; and it is observed that the masses both of ore and veinstone are of no determinate shape, and have generally the appearance of being corroded. Are we to conclude, in such instances, that the hard minerals, and metallic ores, have been formed in the substance of the clay by some peculiar elective affinity, or that they once occupied the cavity of the vein, and have been all subsequently decomposed, except the remaining detached masses? I should be more inclined to adopt the former opinion; but it must be allowed, that there are inexplicable instances of the disappearance of minerals, which formerly existed in veins.

The formation of one mineral upon the crystals of another, and the disappearance of the crystal which has served as the mould, is indeed a common phenomenon in many English mines. I have before me a mass of rock crystal from Durham, formed on cubic fluor spar, but the crystals of the latter have entirely disappeared, leaving nothing but the impression of their form. In the mines of Derbyshire, incrustations of calamine are formed on calcareous crystals, taking the shape of the dog-tooth spar; but in these false crystals, no trace of the interior crystal is left. Certain local causes also appear to influence the crystallization of minerals in different districts, and to dispose them to take peculiar secondary forms, which may be considered as appropriate to the minerals of that district. The pyramidal crystallization of carbonate of lime, called the dog-tooth spar (*chaux carbonatée metastatique* of Haüy,) is abundant in some of the mines of Derbyshire, whilst the same mineral rarely assumes that form in the mines of Northumberland and Durham, but is crystallized in other forms, which are equally rare in the Derbyshire mines. Fluor spar, and sulphate of barytes, have appropriate forms in different districts, from which any deviations may be considered as vari-

eties. The causes which occasion this diversity of secondary forms, in minerals whose constituent parts, appear by chemical analysis to be precisely the same, are unknown; nor are we able to explain, in what manner the crystals before mentioned have disappeared, but these facts prove, that the powers of nature extend beyond the present limits of science; and it is more consonant with the true spirit of philosophy, frankly to acknowledge our ignorance, than to form systems from imperfect data, which can only serve to perpetuate error.

Metallic ores in rounded fragments, and grains of native metals are frequently found in the sands of rivers; they have been carried there by torrents or inundations; the rocks in which they were originally formed, having been disintegrated or decomposed. The metals, gold and platina, being indestructible by the action of air, water, or the mineral acids, remain for ages unchanged, in the form of minute grains. The oxide of tin is a very heavy and hard mineral; and it is owing to its weight and indestructibility, that it is found in the sands of rivers, or on the sea shore, where it sometimes occurs in considerable quantities, and is separated from the sand or alluvial soil by directing streams of water over it: hence such works are in Cornwall called Stream Works. With the pebbles of tinstone, there are fragments of granite and other rocks, which serve to indicate, from what mountains in the vicinity the stream tin has been washed out. Particles and small pieces of gold are sometimes found with stream tin, in the sands of Cornwall.

Gold being, as before stated, less subject to chemical change than the other metals, is found in the sands of rivers in various parts of the world, particularly in Africa and South America. A considerable part of the gold obtained from Africa, is procured by washing the sand of rivers; it is found in small grains called gold dust. It has been remarked, that in certain parts of rivers the sands were rich in gold, which seemed to be renewed after heavy rains, and yet but little gold was found in the sands higher up the river. No satisfactory explanation has been offered, respecting the limitation of the auriferous sands to certain localities. Facts have recently been stated to the author, by a gentleman connected with the gold mine companies in North Carolina, which appear to elucidate the periodical renewal of gold in the African rivers. About the year 1810, gold was found in the beds of several rivers in North Carolina: one mass was obtained weighing 28 lbs. Afterwards grains of gold were discovered in the beds of several of the rivers and brooks both of North and South Carolina, and of Georgia. For some years after gold had been discovered in these States, the inhabitants were content with searching for gold in the beds of the brooks and rivers after heavy rains. One of the proprietors of a gold stream, having noticed that it never yielded

gold above a certain point, where a small brook entered into it, was induced to trace the brook to its source, and discovered in the adjacent rocks, veins of quartz, which were found to contain pieces of native gold, and were subsequently worked as mines. It is highly probable that in Africa, the sands in certain parts of rivers become auriferous, by the depositions from rivulets that flow into the main stream.

Mr. Hennah, of Plymouth, has in his collection several pieces of native gold, varying from the size of a bean to that of a hazelnut; they were found in stream works near St. Austel. He has also a specimen of stream tin, eight or nine inches in length, and five or six in breadth, which was evidently once part of a vein. In the same stream-work they could distinguish at different depths, the different veins from which the ore had been washed out. The pebbles of tin ore have in some situations been washed into the sea, and afterwards covered by beds of clay or gravel. In Mount's Bay, south of the town of Penzance, there was formerly a bed of stream tin, worked under the sea. The stream tin covers the killas or slate rock of the country, and is covered by a bed of clay: a perpendicular shaft or tunnel was sunk through the clay, and the bed of stream tin was worked like a bed of coal, the clay forming the roof. (See Plate VII, fig. 8.) The workings were continued under the sea, but were at length inundated and discontinued. The bed with pebbles of tinstone, is seen covering the beds of slate; upon this is a thick bed of water-tight clay, over which the tide rolls. An iron cylinder was sunk through the clay as a shaft to the tinstone, which was worked like a bed of coal and drawn up the cylinder.

The following is a summary account of the geological localities in which the different metallic ores are generally found:—

Platina, and the recently discovered metals palladium, rhodium, osmium, and iridium, have chiefly been found in the sands of rivers.

Gold and silver are found in primary and transition rocks, in porphyry and sienite, and in the lowest sandstone. Gold has been occasionally discovered in coal, and very abundantly in the sands of rivers, and sometimes in volcanic rocks. Silver is very frequently associated with lead, in different proportions, in the lead ores of Great Britain: in some of them, the quantity is so considerable, as to be worth the expense of extracting it from the lead, by calcination.

Mercury is found in slate, in limestone, and in coal strata.

Copper, in primary and transition rocks, in porphyry, sienite, and occasionally in sandstone, in coal strata, and alluvial ground. Masses of native copper of many thousand pounds weight, are said to be found on the surface, in the interior of North America.

Iron, in every kind of rock.

Tin, in granite, gneiss, mica-slate, and slate.

Lead and zinc, in primary and transition rocks, particularly in the mountain limestone; also in porphyry and sienite; in the lowest sandstone, and occasionally in coal strata.

Antimony, in primary and transition mountains; it is also found in porphyry and sienite.

Nickel, bismuth, cobalt, in primary mountains, except limestone, trap, and serpentine. Cobalt and nickel also occur in transition mountains, and in sandstone.

Arsenic, in primary and transition mountains, and in porphyry.

Manganese, in primary and transition mountains, and occasionally in the lower stratified rocks.

Molybdena and tungsten, uranium, and titanium, in granite, gneiss, mica-slate, and slate. The latter metals, with chronium, columbium, cerium, and tellurium, are very rare in nature, and can only be reduced to the metallic state with great difficulty.

OBSERVATIONS ON ELECTRO-CHEMICAL EXPERIMENTS, THAT ELUCIDATE THE FORMATION OF METALLIC ORES.

The experiments and discoveries, recently made by the aid of voltaic electricity, have tended much to elucidate the formation of metallic ores in different rocks, as I anticipated twenty-five years since would probably be the case, see p. 357. The connection between voltaic electricity and magnetism, if not their identity, is now clearly established, but this discovery has led to some erroneous opinions and statements, respecting the direction of metallic veins, and its relation to the magnetic meridian, with which there can be no connection whatever. The angle of the magnetic meridian being ever variable, and having a range of fifty degrees from east to west, we cannot admit, that the direction of metallic veins is in any way dependent on its influence, unless it could be proved, that metallic veins changed their position and traveled east and west, with the variation of the magnetic needle. This would indeed be "an *astounding fact.*"—See *Athenæum,* Sept. 3, 1836. Report of the British Association.

Mr. Crosse of Broomfield, Somersetshire, gave an account at the meeting of the British Association, at Bristol, August, 1836, of various experiments made with a voltaic apparatus, which had retained its energy for a whole year, by the agency of pure water only. The water from a cavern in the Quantock hills, he submitted to the action of this apparatus for several days, and succeeded in procuring calcareous spar, and arragonite (similar to what had been found in the cavern,) by the percolation of water, over limestone and clay slate. In a similar manner, he succeeded in obtaining from metallic solutions, carbonate of copper, phosphate of copper, arseniate of copper, carbonate of lead, sulphuret of iron, and many other minerals; and, what is more extraordinary, he succeeded in the formation of quartz crystals (by the same apparatus) from fluosilicic acid.

Mr. Fox, of Falmouth, has made numerous experiments, proving the agency of voltaic, or what he calls electro-magnetic agency, on the forma-

46

tion of metallic ores in veins. He is of opinion that different saline solutions may be contained in the minute fissures, and interstices of rocks, which may place these rocks in different electrical conditions with respect to each other, and he suggests, that the high temperature of water in the deeper parts of veins, may give it a great power of dissolving saline or earthy minerals, and that the water in ascending would lose its temperature, and deposit its contents on the sides of veins.

The formation of arragonite and calcareous spar from the same water, as it passed over rocks of slate or limestone, as above stated by Mr. Crosse, was evidently the result of the different electrical conditions of the two rocks; for Mr. Crosse produced both these minerals from the same water, at the opposite wires or poles of his voltaic apparatus. It is, I think, highly probable that the matter that forms metallic BEDS, between two beds of rock, was originally diffused through one of them, in a state of solution, and was afterwards separated by electrical agency and collected into an irregular stratum or bed. The passage or transference of one mineral substance through another, by electro-chemical action, has been fully established, and it is not improbable, that the same agent may be also operative in forming those hard concretionary masses or strata, often found in beds of sand or marl. Such are the irregular strata of fibrous gypsum in red marls, running in different directions through it, and the siliceous masses and concretions in green sand; see p. 254.

CHAPTER XXI.

ON SUBTERRANEAN RIVERS AND CURRENTS, AND ON CAVERNS.

Occurrence of Subterranean Currents and Rivers in various Parts of the World.—The Principal Agents in the Formation of Caverns.—Remarkable Cavern and Cascade in the Speedwell Mine, Derbyshire.—Subterranean Currents and Caverns generally in calcareous Mountains.—The Reason explained.—Subterranean Currents connected with the Surface Water, deposit Animal and Vegetable Remains between ancient Strata, proved by Facts.—Caverns with Bones of extinct Species of Animals in Germany and France, intermixed with Human Bones, and Implements of Industry.—Bones introduced into Caverns by Subterranean Currents and other Causes, and at different Epochs.—Bone Cavern at Kirkdale, in Yorkshire, and at Banwell, in Somersetshire.—Bones found in the Clefts and Fissures of Rocks forming Osseous Breccia in various Parts of Europe, and in New Holland.—Epochs of their Deposition, supposed to be different in distant Parts of the Globe.

Beside the fissures and spaces filled with metallic matter, that occur in the older rocks, as described in the preceding chapter, there are empty spaces or caverns, that sometimes extend far into the interior of mountains, and sometimes descend to considerable depths. Almost all large caverns occur in limestone rocks, chiefly of the transition and secondary class. Caverns in some instances may have been formed by the upheaving or subsiding of rocks, but they have most frequently been excavated by subterranean currents of water, which have enlarged original fissures, or carried away the beds of soft clay or loose sand, that were interposed between hard strata. Many large caverns have streams of water constantly running through them, and after heavy rains they are often gorged with water, which issues with violence from their mouths. This is the case with the great Peak Cavern, near Castleton, in Derbyshire.

The action of subterranean currents of water, has scarcely been attended to by geologists, but were it better understood, it might probably afford a satisfactory explanation of several facts in geology, that have been regarded as anomalous, particularly that of the occurrence of bones in caverns which have no opening to the surface.

The mountain or transition limestone of Craven, in Yorkshire, forms, in many parts, a nearly flat elevated surface of table land, covered with vegetation, but intersected by numerous vertical fissures or chasms of vast length and depth, varying from a few inches to a foot or more in width. Many of the fissures widen as they descend, and at the bottom, streams of water may be frequently heard running. During snow, it is not uncommon for sheep to be lost in these chasms, and the whole surface is extremely dangerous to traverse in the dark. Limestone plains,

intersected by such fissures, may be regarded as natural traps for herbivorous animals, into which they may fall in droves, when chased by beasts of prey. Their bones may either stick fast in the fissures, and be afterwards inclosed in calcareous stalactites, or they may be carried by subterranean currents into caverns which have no communication with the surface. Such was the cavern at the Bull's Eye mine, near Worksworth, in Derbyshire, which was opened by mining operations in the year 1663, and contained the entire skeleton of an elephant.

There is a considerable river called the Pinka, in the cavern at Adlesberg, in Carniola, which forms a subterranean lake, where it appears to be lost; but the river emerges again on the north side, and takes the name of Renz. This cavern is one of the largest in Europe; it extends for several leagues into a calcareous mountain, situated between Laybach and Trieste, and contains the bones of bears and other animals, in the mud that forms the floor of the cavern, or rather series of caverns that are connected by passages with each other. There are numerous caverns and grottoes in the vicinity of Adlesberg, and the surface of the country is in various parts broken by depressions from the subsidence of the roofs of these caverns. Doubtless there are subterranean rivulets in all these caverns, which are continually in action, and are undermining and wearing down the rocks that support the strata above them.

In Derbyshire, and the district called Craven, in Yorkshire, beside the subterranean rivulets before mentioned, there are currents of water incessantly in action, which are only discovered by mining operations. The Speedwell mine near Castleton, in Derbyshire, is a subterranean tunnel and canal, nearly half a mile in length, penetrating into the center of a mountain composed of metalliferous limestone: the descent to the canal is by a flight of steps, about forty yards in depth. The mountain is intersected by numerous metallic veins, and the proprietors of the mine intended to carry the tunnel and canal through the whole extent, in order to discover the veins, and have ready access to work them, and bring out the ore. The stone was obliged to be excavated by blasting, and before every explosion, the miners retired for safety to a distance in the tunnel. When they had proceeded in this manner about eight hundred yards, they were greatly alarmed after a blast, to hear the tremendous roaring of a torrent, and fled towards the entrance of the tunnel. A miner, who was working there at the time, informed the author that he thought there was no chance of escaping from immediate destruction; however, when they had retreated a considerable distance, they perceived the rushing sound to grow less alarming; they then halted awhile, and took courage to return, when they discovered that the last blast had made an opening into a spacious cavern,

and that a torrent of water was falling from a considerable height into a vast chasm on one side of it. The loud roaring of the water was greatly increased by the echoes of the cavern; for in the roof of this cavern there is a wide opening into an upper cavern, the top of which is not visible from below, even with the illumination of fireworks, which those who show the mine generally take with them.

By the ceaseless action of such internal currents of water, falling into original fissures, or descending through soft strata in mountains of compact limestone, it is easy to conceive that caverns of great extent may be excavated. A very few years since, a miner, in driving an adit or passage into the heart of the well known rock called Matlock High Tor, discovered a large cavern and a lake in the middle of the mountain. Many of the coves or caves in Craven, in Yorkshire, were originally caverns, the roofs of which have fallen in; they have streams of water rushing into them, forming subterranean cascades. The cavern called Weather-Coat Cove, and the rocks at Gordale Scar, offer illustrations of the effects of subterranean currents.

Where powerful springs of water rise at once to the surface, it is obvious that they are not the result of slow percolation through porous strata, but that they are the outlets of internal streams or rivers. The river Air rises at the foot of a perpendicular limestone rock, called Malham Cove, in Craven; it is a broad, powerful, and permanent stream, before it receives any tributary rivulets from the adjacent valleys. It is generally believed that the subterranean stream which gives rise to the river Air, is connected by internal passages with Malham Tarn, a mountain lake, situated at a distance. Perhaps the spring at Holywell, in Flintshire, may be cited as offering a similar proof of under-ground rivulets.*

The reason why subterranean streams of water, and extensive caverns, should chiefly occur in districts where compact transition, or mountain limestone, is the prevailing rock, will admit of an easy explanation. Slate rocks are almost always intersected by perpendicular fissures, which carry off the water, and prevent its accumulating in large streams; and the secondary strata in England are generally too soft, or too much broken, to form the roofs of extensive caverns, or the beds of subterranean rivers. In the vicinity of the Alps, where the secondary limestones are extremely hard and compact, they contain caverns, and afford a passage for subterranean currents. A large cavern has, however,

* This conjecture, stated in the former edition of this work, is rendered extremely probable by the recent discovery "of a subterranean river in a mine called Blain y nant, near Mold, which passes through several large caverns, and is supposed to supply St. Winefred's Well, at Holywell, which is twelve miles distant."—*Times Paper*, Dec. 13, 1837.

been recently discovered in mica slate and common slate, in the Isle of Thermia, one of the Cyclades, at the height of 1400 feet above the level of the sea. M. Virlet, who visited the cavern, attributes the excavation to subterranean streams of water, as there is a considerable deposition of mud and bluish clay at the bottom of it.—*Séance du 20 Fév.*, 1832, *de la Société Geologique de France.*

It is admitted by M. Desnoyers, in the report from which this account is extraced, that the existence of such a cavern in rocks of mica slate and slate, is a new fact in geology. There are several thermal springs in the island, which indicate the action of subterranean heat. This agent may, perhaps, have been in some manner the cause of the formation of the cavern; it is, however, supposed by some, to have been an excavation formed by mining operations at a remote period.

Instances of rivers of considerable magnitude sinking into the earth, and emerging again at the distance of several miles, have been long known in many countries: it is not the object of the present chapter to enumerate them, but to direct attention to those subterranean streams, that have no apparent connection with the surface. It cannot be doubted, however, that the rivers which run only for a few miles under ground, and emerge without any apparent loss of water, must effect considerable changes in the strata during their subterranean course. In some cases rivers are absorbed into caverns, in others they merely sink into softer strata, as takes place with the river Rhone, about twenty miles from Geneva, at what is called the *Perte du Rhône.* See Travels in the Tarentaise, vol. ii. p. 264.

The subject of subterranean currents has scarcely attracted the attention of English geologists, but it is beginning to excite inquiry in France, where the practice of boring for water is becoming general, and has brought to light some interesting facts. In the report of M. Desnoyers, before referred to, several of these facts are described, but he previously states the observations of MM. Boblet and Virlet, on the closed valleys or gulfs in central Morea, called *Katavotrons*, "into which torrents of water amassed during rainy seasons are precipitated, carrying with them the mud with which they are colored, the skeletons of animals, with fragments of shells and plants mixed with gravel, which they introduce into subterranean cavities. The water again springs up at a great distance from the sea pure and limpid. This circumstance serves to explain the filling of many caverns; may it not also explain the sinuous passages filled with sand and gravel, between strata which are found at great depths from the surface, in the environs of Paris?"

From the borings and sinking for water in different parts of France, it is evident that considerable subterranean streams

which are occasionally discovered, have somewhere a connection with the surface waters. In a well sunk at Tours, in 1829, in the lower chalk, to the depth of 330 feet, the water rose rapidly for some hours, bringing with it much fine sand, fragments of thorns, and seeds of marsh plants, with land and fresh-water shells unchanged.

A remarkable fact recently occurred at Reinke, near Bochum, in Westphalia. A well was sunk to the depth of a hundred and forty-three feet, when the water rose to near the surface, bringing with it small fish from three to four inches in length. The nearest currents of surface water are from two to five leagues distant from the well. How small is the proportion of seeds, shells, fish, sand or gravel, that come to the surface, compared with those who are arrested in their progress, and finally fill up the subterranean passages and change the direction of these underground currents! What a natural explanation does this offer, of many facts which have embarrassed or deceived geologists! It may be well for the reader to refer to what was stated in Chap. XIII, respecting the teeth and bones of small land quadrupeds found in the calcareous slate of Stonesfield. I there observed, that it was probable they had been brought into their present situation by subterranean currents, during the tertiary epoch,—and I am inclined to believe, that the traces of such subterranean currents would be discovered, could the internal structure of the strata be fully laid open.

The subject of subterranean currents becomes interesting to the geologist when connected with caverns; indeed, caverns themselves would scarcely deserve attention, were it not that they frequently contain skeletons or bones of large mammiferous animals, belonging to species that no longer exist in Europe, and are supposed to be extinct elsewhere. Many of these caverns were closed when first discovered, and some of them have been recently found to contain human skulls and bones, mixed with the bones of extinct species of quadrupeds: hence, we are led to inquire in what manner these bones were introduced into the caverns and at what epoch. The bone caverns in Germany will be first described, and then some notice will be given of the caverns recently discovered in France, containing human skulls and bones: and lastly, we shall notice some of the bone caverns in England.

It has long been known to naturalists and travelers, that there are numerous caverns in the calcareous mountains of Germany and Hungary, the floors of which are covered with clay, enveloping a prodigious quantity of bones and teeth of carnivorous animals. The bones in these caverns are nearly the same, over an extent of above one hundred leagues. More than three fourths

belong to species of bears that are now extinct;* two thirds of the remaining part belong to an unknown species of hyena; a smaller number belong to a species of lion or tiger, or of the wolf or dog; a very few belong to small carnivorous animals, allied to the fox and polecat. The bones are nearly in the same state in all these caverns: they are found scattered and detached, partly broken, but never rounded by attrition, and consequently not brought from a distance by water. They are rather lighter and more fragile than recent bones, but still preserve their true animal matter, containing much gelatine, and are not in the least petrified. The bones are all enveloped in earth which is penetrated with animal matter: except a few bones on the surface, of a different kind, which have been brought there at a later period, and are less decomposed.

The most remarkable of these caverns are those of Gaylenreuth, on the left bank of the river Wiesent, in Bavaria: they vary in height from ten to forty feet, and are connected by narrow low passages. The animal earth intermingled with bones, is in many places more than ten feet deep; and according to the account of a German writer, M. Esper, would fill many hundred wagons. The cavern at Adlesberg, in Carniola, before noticed, is much larger than any of the bone caverns in Germany: the series of caves which are connected, are of variable dimensions, and are stated to extend more than three leagues in a right line, at which distance there is a lake that prevents further access. The floors of these caverns are covered with indurated clay, enveloping the bones of bears, and other carnivorous animals, similar to those in the caverns of Germany and Hungary. In one part of this cavern, or series of caverns, the entire skeleton of a young bear was discovered, enveloped in clay or mud, between blocks of limestone which lay on one side of the cave. Bones are found along the cavern, for several miles from the entrance, not only buried in mud, which forms the floor, but among heaps composed of blocks of limestone, and yellow mud or clay. The entrance to this cavern is situated near the great road from Trieste to Laybach.

In many of the caverns in the south of France and also in Belgium, bones are found in the mud and gravel which form the floor, but which is sometimes coated with stalagmite. The intermixture of human bones and rude works of art, with the bones of extinct species of mammiferous quadrupeds in some of these caverns, has excited much attention. In some instances the human bones appear to be reduced to what has been called the

* The most common species of bear in these caverns, the Ursus Spelæus, was the size of a horse. The fossil hyena was one third larger than any known living species.

same fossil state, as that of the animal bones with which they are intermixed. Much more importance has been attached to this circumstance than I think it deserves; for, in the first place, few if any bones of mammiferous land quadrupeds found in caverns, or in diluvial soil, can be properly said to be fossilized, as they retain a part of their original matter; and, secondly, the experiments of Dr. Jenner, stated in page 20, prove, that when recent bones are immersed in mud containing pyrites, or solutions of iron, they become more or less fossilized in a few months. The caverns in the south of France, according to M. Desnoyers, were some of them partly filled with bones of quadrupeds before human bones were introduced into them; others appear to have been empty. He observes, how often may these caverns have served as burial places to the ancient inhabitants, or, at a more recent period, as places of retreat during religious persecutions, from the persecutions of the Druids to those of the Huguenots. The historian Florus, (he adds,) expressly informs us, that the inhabitants of Aquitaine, an artful people, retired into caverns, and that Cæsar gave orders to have them closed in their retreats, and left to perish. "Aquitani, callidum genus, in speluncas se recipiebant, jussit includi."—*Flor.* lib. iii, cap. 10.

Add to this, from the known habits of several races of the ancient Celts to live in caverns, of which many proofs are preserved in the provinces bordering the Loire and the Rhone, it may be readily believed, that the human bones with pottery, in the caverns of part of ancient Aquitaine and the Narbonnaise, belonged to some of the wretched Gauls, whom Cæsar caused to perish in these caverns.

Where, says M. Desnoyers, the mixture of human bones and those of quadrupeds is more complete, currents of water might have effected a movement and intermixture (*remaniement*) of a more recent date. The hatchets of flint and other rude instruments found in these caves, are such as are found also in the tumuli of the ancient Celts, and were in use in the time of Cæsar.

M. Desnoyers thinks the most ancient of these bones are Gaulic or Celtic: others belong to a more recent epoch. He examined the rich collection of Celtic coins in the Bibliothèque Royale; on many of them he observed figures of animals, such as the boar, the horse, the wild ox, and the stag, and more rarely, symbolic or monstrous animals; but no figures of the rhinoceros, or of any extinct races, which, had they been co-existent with man, there might have been reason to expect.

M. Tournal, who first discovered human bones in the cavern at Bize, maintains a contrary opinion, and he applies the same conclusions to the bones of mammiferous animals in other caverns. The caverns of Bize (Aude) contain bones of the stag, the camel, the roebuck, the antelope, and bear; those of Som-

mières (Gard) contain bones of the rhinoceros, the ox, the horse, the stag, and the hyena. M. Tournal concludes from the state of the bones, that they are antediluvian, and that before the last general catastrophe, (*cataclysme*,) southern Gaul was inhabited by man, together with a great number of species of mammiferous animals now extinct.

The cavern of Rancogne, situated three leagues from Angoulême, is one of the largest in France, and has long been celebrated for its quantity of stalactites; but under the stalagmite and alluvial soil on the floor of the cavern, a great quantity of human and quadrupedal bones have been found, mixed with fragments of pottery and with pebbles from the adjoining rocks. A brook still traverses this grotto. The river Tardonère, which runs at a little distance, loses a part of its waters in other gulfs in the country; it often overflows, and has penetrated into the cavern of Rancogne. The traditions of the country preserve the remembrance of the cavern, having served the inhabitants as a place of refuge at different periods; and that wolves, which abound in the forest of Braconne, commonly retire into it, and carry with them their prey, and human bodies, which they exhume from the neighboring cemetery.

This mode of filling the cavern, (observes M. Desnoyers,) differs much indeed from the antediluvian theory of M. Tournal. Some grottoes contain human bones in the upper alluvial soil, over a bed of stalagmite, under which there is a lower bed with bones of quadrupeds.

The cavern of Miallet, near Andure, (department of Gard,) is situated near the banks of the river Gardon. It occurs in magnesian limestone, about one hundred feet above the valley; the lower bed, or floor of the grotto, is a sandy magnesian limestone, covered with a thin bed of stalagmite, and also in several parts, with a bed of argillaceous mud, about five feet in thickness. In this bed, the heads and bones of bears were found in great abundance, and in a high state of preservation: they were larger than the common cavern bear, (*Ursus spelæus.*) A few fragments of bones of the hyena, of ruminating animals, and of birds, were also found with them. Under the stalagmite, and a thin stratum of sandy mud, a great number of human bones were discovered in different parts of the cavern. Towards the farther end of the cavern, the human bones are incontestably mixed with the bones of bears, which predominate in that part: but near the entrance, human bones predominate, and appear somewhat more recent. Upon the ossiferous or bone mud, and under a projection of the rock, a human skeleton was discovered almost entire, near which was a lamp and a small figure in baked clay, and at a little distance were copper bracelets. In others parts of the cave were found fragments of rude pottery, and instruments of flint, the

workmanship of a preceding age. The human heads are stated to present indications of belonging to the Caucasian race, but they have a depression of the skull, which M. Tessier supposes to have been produced artificially.

M. Tessier distinguishes three periods during which this grotto was filled: 1st, An antediluvian epoch—that of the bears, which belong to an extinct species; these he supposes may have lived in the cavern during successive generations, or may have been driven there by some great convulsion. 2d, An epoch of incipient civilization—that of the ancient Celts, whose bones are intermixed with rude implements of industry. 3d, A Roman epoch, indicated by more perfect works of art.

With respect to the mixture of human bones with those of bears, it does not prove that the latter were contemporaneous with man, because it is obvious that they could not have lived together in the same cavern. The mixture may have been effected by the action of water, or by artificial excavations in the original bone bed for sepulchral purposes.

In a subsequent examination of this cavern, M. Tessier discovered, that in those parts where the bones of bears and men were much intermixed, bones of bears incrusted with mud were attached to the roof of the cavern. This proves that the cavern had been filled with bone mud (*limon à ossemens*) by the violent action of water, otherwise the bones of bears that inhabited the cavern, would all have been found at the bottom. It is most probable that the cavern was originally inhabited by bears, and afterwards inundated by mud and water; that, at a later epoch, it became the residence or sepulcher of a rude people, but was subjected to a second inundation, which drifted the bones of bears and men into the distant low passages. At a still later period, the cavern had been occasionally used for a sepulcher by the Romans, as a skeleton, with a lamp and bracelets, were discovered on the surface of the floor. M. Tessier says, that the river Gardon, before it had excavated its present deep bed, might have occasionally caused great inundations, which filled the cavern with water. Whatever theory may be adopted respecting the former inhabitants of the cavern of Miallet, the bones attached to the roof prove the agency of water, and sufficiently explain the cause, by which the remains of bears and men may have been intermixed.

Perhaps it may yet be regarded as uncertain, whether these human bones were or were not coeval with those of the cavern bear, the rhinoceros, and other animals; for we have no decided evidence when these animals became entirely extinct. I am inclined to believe, that the mastodon of North America existed there much later than is generally admitted; the reason for this opinion will be given in the following chapter. Secondly, We

cannot assign a reason why man might not have existed in some period of the tertiary epoch, except that his bones are no where discovered in the regular tertiary strata. The country that could give support to the mammoth, or ancient elephant, to the mastodon and the elk, might, for aught we know to the contrary, be also suited for the residence of man.

It is very different with respect to the secondary strata, for though many of these strata have once been dry land, or in the vicinity of dry land, yet we no where find in them the bones of herbivorous mammalian quadrupeds, that could have been with man joint tenants of the globe; nor even do we find bones of carnivorous quadrupeds, that might have preyed upon the former, had they existed.

During the tertiary epoch, however, there is evidence of great revolutions of the surface, by the elevation of mountain ranges, which might, perhaps, render the earth unfit for the continued existence of the human species, and I am inclined to believe, that the occurrence of human bones in caverns, or in diluvial beds of gravel, sand, or mud, has not yet invalidated the position, that the creation of man was posterior to the tertiary epoch.

We come now to the English caverns: they have been more recently the object of attention than the bone caverns of Germany: their discovery may be said to have given a new impulse to geology, both in this country and on the continent, for which we are chiefly indebted to the enlightened and indefatigable exertions of Professor Buckland, of Oxford.

Single skeletons of large quadrupeds have formerly been discovered in caverns in this country; but we had no authentic account of the bones of carnivorous animals having been found in any English caves, previously to the year 1821, when some laborers, working in a quarry at Kirkdale, near Kirby Moorside, in Yorkshire, discovered an opening covered over with rubbish and earth, about one hundred feet above the neighboring brook. This was the mouth of a low cavern, extending about two hundred feet into the rock. The floor of the cavern was covered with broken bones, and teeth of various animals, encased in a stratum of mud about a foot thick. Fortunately this cavern was examined soon after its discovery by Professor Buckland, of Oxford, who has published a very luminous account of its structure and contents, elucidated by references to the most remarkable caverns in other countries which he has visited, containing the bones of carnivorous animals. The bones in the Kirkdale Cave are broken and gnawed, and some of them preserve the marks of the teeth which have fractured them. Even the excrements of animals, similar to those of the hyena, have been discovered with them. The bones in this cave differ much from those in the caves of Germany, as a great number of them belong to herbiv-

orous animals, and the carnivorous animals whose remains are most abundant, are hyenas.

Among these remains, Professor Buckland has ascertained bones of the following orders:

Carnivorous Quadrupeds.—The hyena, tiger, bear, wolf, fox, and weasel.

Pachydermata.—The elephant, rhinoceros, hippopotamus, and horse.

Rodentia, or Gnawers.—The hare, rabbit, rat, water-rat, and mouse.

Ruminant Animals.—The ox, and fragments and bones of three species of deer.

Birds.—The raven, pigeon, lark, snipe, and a small species of duck.

From the great number of bones of the hyena found in this cave, Professor Buckland infers, that it had long been the habitation of these animals. It is their ascertained habit, partly to devour the bones of their prey; they also devour the dead bodies of their own species; like wolves, they are gregarious, and hunt in packs. From the habits of the hyena, he explains the occurrence of the remains of large herbivorous quadrupeds, like the elephant, in so low a cave as that of Kirkdale; they have been dragged into it by these voracious animals. Several English caverns have since been explored. In some of them, there are bones both of herbivorous and carnivorous animals, similar to those in the Kirkdale Cave. These caves are described in Professor Buckland's valuable work, entitled *Reliquiæ Diluvianæ*.*

That the caverns in which the bones of carnivorous animals are found in such prodigious quantities, were the retreats of some of these animals, cannot be doubted. Many circumstances, described in the account of the Kirkdale Cave, can only be explained by admitting it. There are, however, other circumstances, particularly in the caves of Germany, which would imply, that part of the bones belong to animals that had fallen through fissures, which formerly opened into these caverns, or that the bones themselves had been carried by currents of water through subterranean passages into these caverns, as before explained in the present chapter. In the cave at Gaylenreuth, there are

* The caverns near Banwell, in Somersetshire, contain the most numerous collection of mammalian bones that have recently been discovered in England. The bones amounted to several waggon loads, and are principally those of herbivorous animals. They were intermixed with mud and black earth, a decomposed animal matter and sand from the Severn sea, which flows about six miles from Banwell. The only aperture at first known was a very narrow fissure. A lateral aperture has since been discovered, sufficiently large to have admitted bodies of bears, wolves, and oxen. About three miles from Banwell, in the fissures of mountain limestone, the bones of elephants and enormous bears, with those of tigers, oxen, and stags, have been found.

rounded fragments of limestone, intermixed with the bones, and the entrance of some of the caverns *is much too small* to have admitted the animals whose bones are found in them. It is also probable, that a violent convulsion of nature, as a rising deluge and the fierce war of elements without, might have driven, under the strong impulse of alarm, numerous animals of different species into the same caverns, where they devoured each other, and their bones have been intermixed with those of the former inhabitants. The entrances of many of the caverns, and the caverns themselves, were doubtless formerly more lofty than at present; they have been gradually lowered by the subsidence of the upper strata. Indeed, it is admitted, that the caverns and grottoes in the neighborhood of Adelsberg, have occasioned numerous depressions of the surface. Such an effect must generally take place, in a greater or less degree, with the strata over caverns.

The occurrence of the bones of quadrupeds in the clefts or fissures of rocks, intermixed with fragments of the rock, and cemented with them into a kind of breccia, is very common in many of the calcareous rocks adjoining the Mediterranean sea. The osseous breccia of Gibraltar, is well known: the calcareous matter which has been infiltrated into the fissures, and forms the cement, has generally a reddish color, and contains so much phosphoric acid, from the decomposition of animal matter, as to become luminous in the dark when scraped. The bones in the fissures surrounding the Mediterranean, belong chiefly to herbivorous quadrupeds, but they are sometimes intermixed with marine shells, indicating a great change in the level of the rocks, subsequent to the filling of the fissures.

Osseous breccia, similar to that in Europe, has been recently discovered by Major Mitchel, in the rocks bordering Wellington Valley, in New Holland. The breccia contains bones and fragments of rock, with the same red calcareous cement as the osseous breccia of Gibraltar, &c. According to the examination of Cuvier and Mr. Pentland, some of the bones belong to different species of the kangaroo, and animals of the same genera that exist in New Holland, but others belong to species hitherto unknown to naturalists. Among these bones there are the remains of a species of elephant: a fact extremely interesting, as it proves that, in the ancient condition of the globe, this part of its surface supported animals more analogous to those of Asia and Africa, than any which existed upon it, when first discovered by Europeans. In the report to the Geological Society of France, 1831, it is observed—"Thus we have in New Holland, a deposition of osseous breccia similar to those of Europe. *Were these depositions cotemporary?* This is not very probable; the analogy has consisted in the mode of formation; different catastrophes, at

different epochs, may have destroyed the great animals of the Ohio, of the Irrawadi, of the north and central parts of Europe, and of Australia, and buried their bones in fissures and caverns, or in beds of clay and gravel. But whatever was the epoch of the deposition in New Holland, the organization of animal life was then, in a great part, the same as at present; since we find in the osseous breccia, the types of that class of animals that are still peculiar to the country, but always accompanied by bones of genera, (the mastodon and elephant,) which are altogether unknown there."

The depositions of calcareous earth pendant from the roofs of caverns, called *stalactites*, and those upon the floors of caverns, called *stalagmites*, are formed by the evaporation of water, holding calcareous earth in solution. A drop of water, in evaporating, deposits a pellicle of limestone, which is increased by succeeding depositions, until a small protuberance of solid limestone is formed, nearly the shape of a drop of water. This protuberance becomes enlarged by water trickling over it, and takes the shape of an icicle. The water that drops upon the floors of caverns, sometimes deposits a thick coat of limestone over the whole floor; but in those parts where the drops fall most frequently, a more copious deposition of calcareous earth takes place, in the form of tubercles: these are the stalagmites. In some instances, the stalactites and stalagmites increase, until they nearly fill the whole cavern.

CHAPTER XXII.

ON THE DESTRUCTION OF MOUNTAINS, AND THE FORMATION OF SOILS; AND ON ALLUVIAL AND DILUVIAL DEPOSITIONS.

Erroneous Opinions respecting the Growth of Stones, supported by the Authority of John Locke.—On the Causes in present Operation that wear down Rocks.—Alluvial and Diluvial Depositions.—Rapid Destruction of Mountains dependent on their structure.—Fall of Mont Grenier in Savoy; and of other Mountains in the Alps.—Alpine Inundations from the Breaking down of the icy Barriers of Mountain Lakes.—Action of the sea upon Cliffs.—Destruction of Cliffs by Land Springs in Norfolk, and near Boulogne, in France.—Increase of land by Marine and Alluvial Depositions.—Filling up Lakes, and Formations of Deltas at the Mouths of large Rivers.—On the Formation of productive Soils.—Recent Strata formed in Lakes.—Peat and Peat Moors.—Inundations of Sand.—Remains of Elephants and other large Animals, found in the Diluvial Beds in England, and the frozen Regions of Europe and Asia.

Few persons can have travelled a hundred miles through any country, without having seen beds of gravel, or of rounded stones, or fragments of rock scattered in different directions, which were evidently never brought into their present situation by the labor of man. In some instances these masses of loose stones, or large fragments of rock, occur on the summits of hills, or on elevated ground, and the stones are altogether unlike any rocks or strata in the adjacent districts. Among the numerous travellers to whom such objects are familiar, it is surprising how few have ever raised the inquiry—"*How did these masses of rock, or beds of loose stones, come here?*" One great reason for this indifference arises from a cause that may surprise geologists. Many well educated persons, who possess much information on various subjects, still entertain the belief that stones grow in the places where they are now found: this belief excludes the necessity for further inquiry. They can also refer to the authority of the ablest philosopher this country ever possessed, for a confirmation of their opinion, should it be controverted.

The celebrated John Locke states, in his "Elements of Natural Philosophy," that "*all stones, metals, and minerals, are real vegetables; that is, grow organically from proper seeds, as well as plants.*"

If any one should think it superfluous to notice this extraordinary passage, in the present age of general information, let him inquire among his friends *whether stones grow?* and he will be somewhat surprised by the answers he may receive.

These scattered fragments of rock, or beds of loose stones, together with beds of sand and gravel, present objects of inquiry of

the most interesting kind. *From what districts were they transported? What were the causes by which they were removed? What was the epoch of their removal?* A farther inquiry also presents itself, as some of the beds of loose stone are rounded, or water-worn, like the shingles on the sea beach, but are now raised many hundred feet above the high-water mark. *By what agents were these beds raised to their present elevation?*

Satisfactory solutions to all these inquiries will probably long remain desiderata in geology, though, in some instances, we can arrive at a high degree of probability, by referring to causes in present operation. These scattered fragments, or masses of rock, with beds of loose stones and gravel, or of superficial sand or clay, are comprised by French geologists under the appropriate name of *terreins de transport*; a name, however, which cannot well be introduced into our language. We shall, therefore, divide them into three groups, adopting the names generally received: Scattered blocks of rock; diluvial beds, or diluvium; and alluvial beds, or alluvium; using the two latter without any reference to theory. *Alluvial beds* consist of the sand, soil, or stones brought down by rivers, and deposited in their beds, or scattered upon their banks, or carried into the sea or into lakes, forming deltas at the mouths of rivers. *Diluvium, or diluvial beds,* comprise beds of gravel, or of stones more or less rounded, that are found in inland districts, and also large and detached blocks of rock, which are now generally called erratic blocks. They are classed as diluvial beds, on the supposition that they were transported during some great convulsion, by deluges or inundations, more powerful than any which are in constant operation.

In order to form a more distinct idea of the causes which have transported the beds and fragments of stone into their present situation we shall first consider the causes that are daily wearing down the loftiest mountains and cliffs, or undermining the solid ground on the sea shore. The disintegration of rocks and mountains is constantly taking place by the incessant operation of atmospheric causes. The infiltration of water into the fissures of rocks, and its expansion by frost, often produces sudden falls of immense masses of rock. The slow operation of descending currents, excavates the soft beds in the lower parts of mountains; and the upper rocks, being undermined, fall, with a tremendous crash, into the vales below. Instances of this kind have occurred in our own times. By both these causes, the process of disintegration is rapidly going on in the Alps; but such is the immensity of these enormous mountain ranges, that ages pass away before any diminution of their bulk is perceived.

In Alpine districts of great elevation, there is also another cause, more exposed to observation, which is ever in action du-

ring the summer months. The snow upon the mountains below the line of eternal congelation, when it begins to dissolve, forms numerous rivulets, that unite into large streams, and descend in cataracts with impetuous force, excavating deep ravines in the lower rocks. To use the words of Professor Playfair, they are "Nature's saws, incessantly at work, cutting down the mountains."

The vignette in the second part of this volume, represents the upper part of the valley of Sixt, in Savoy, in which the water, descending from the Alpine snow on the Buet and other mountains, is seen rushing in numerous cascades to the lower valley. But the most powerful effects of these cataracts may be observed during thunder storms, or after an unusually rapid thaw, when the upper rivulets overflow their accustomed boundaries, and carry with them the loose stones or masses of rock they meet in their descent, and dash them with inconceivable violence into the lower water-falls, breaking down the solid rocks on each side, and deepening and enlarging the ravines into which they fall. The operation of this cause will be again referred to in the following chapter.

We need not indeed travel to the Alps to prove, that the mountains have been, and are still wearing down. The rocky fragments in Borrowdale; the deep ravines made by torrents in the sides of Skiddaw; the immense blocks of granite, called Shap Granite, torn from Wastdale Crag, in Westmoreland, and scattered over the adjacent counties, offer striking proofs of this. Masses of the rocks of Cumberland and Wales, more or less water-worn, occur almost every where, under the alluvial plains of Cheshire and Lancashire. The central parts of England have once had a greater elevation than at present; pebbles formed of the Charnwood Forest rocks, are spread all over the midland counties. Beds of flint gravel, formed by the disintegration of chalk rocks, in which flints were imbedded, occur in many parts of England at a great distance from the sea, or from the chalk districts.

The transportation of these masses of rock, or beds of stones and gravel, cannot have been effected by any thing like the present action of rivers in England, and is generally referred to the more extensive operation of deluges, during great convulsions of the globe; but if we return to the Alps, and view the effects now taking place, we must admit, that it is not always easy to make the distinction between alluvial and diluvial depositions.

Innumerable blocks of granite, and of other primary rocks, torn from the central range of the Alps, are scattered over the calcareous mountains at a great distance from this range, or are spread in heaps in many of the distant valleys. All the great rivers that issue from the Alps, where the valleys open into the plains, have made deep sections, in beds composed of the ruins

of the mountains, and exhibit proofs of the vast destruction that has taken place. The river Doire, where it enters the plains of Piedmont, has cut through a mass of fragments more than 1500 feet in depth; these fragments consist of irregular blocks of granite, mica slate, and serpentine, frequently more than thirty cubic yards in extent, covered by smaller fragments, and by earthy matter from the decomposition of the softer rocks: the fragments decrease in size, as their distance increases from the parent mountain.

Whoever has ascended the lofty eminences immediately below the highest pinnacles of the Alps, can scarcely fail to have received sensible proofs of the daily and hourly disintegration of the mountains. Here, placed nearly above the region of vegetable or animal existence, and surrounded by the sublimest objects in nature, the deep silence which prevails around, is truly solemn and impressive; but it is broken from time to time, by sounds like the rolling of distant thunder, or by a nearer and louder crash, which is repeated by the echoes from rock to rock. These sounds proceed from the falling of avalanches, or from glaciers splitting and discharging the loose rocks upon their surface, or from éboulements of rock, detached from the bare and exposed sides of the pinnacles and aiguilles. The fragments generally fall into the elevated mountain valleys, and are scattered over the surface of the higher glaciers, which extend from thence into the lower Alpine valleys. As the glaciers in these valleys are gradually melting during summer, the ice above progressively moves downward, bearing with it the cargoes of stones on its surface, which it discharges in heaps at its feet and sides. These accumulations of stones are called *morains*. The destruction of granitic and schistose mountains, it has been before observed, is generally effected by water penetrating between the fissures, and becoming suddenly expanded by frost. The overthrow of calcareous rocks is effected in a different manner; and the vast éboulements which they occasion, are more terrific and destructive than the éboulements from the primary mountains, as they generally take place in more thickly inhabited districts.

The destruction of the calcareous mountains in the Alps, depends on the peculiar composition and structure of these mountains. In the year 1821, I passed a great part of the summer in examining the calcareous mountains in Savoy, the structure of which was then not generally understood, or at least had not been described, in any geological work that I had met with. It was generally believed, that the calcareous mountains were entirely composed of beds of limestone, with lofty mural precipices on the upper part; and that the lower parts, sloping from these precipices, were formed of the débris of the limestone. So far from this being the case, the calcareous mountains of the Alps,

which comprise all the English formations, from the magnesian limestone to chalk, alternate, like the English formations, with enormous beds of soft shale and sandstone; and it is to this alternation, they owe the frequent destruction of the upper parts of the mountains.

If all our English secondary formations were, by some powerful cause, elevated six or seven thousand feet above their present level, and the beds bent into curves, constituting several ranges of mountains, we should have precisely what is found in the calcareous ranges of the Alps. This arched form of the calcareous mountains is represented Plate I, fig. 6, and Plate II, fig. 1, and fig. 2, *x*, *y*. Now, if one thick bed of limestone, or a portion of it, be broken off, as at *z*, fig. 2, the action of continued rains on the soft bed on which it rests, will undermine it, until other portions of the limestone will fall down; and if this process take place on both sides of the mountain, the whole of the bed of limestone will fall, except the part which rests flat upon the summit: in this manner, the enormous caps of limestone have been left, like immense castles, that compose the summits of the calcareous mountains, near the lake of Annecy, and in the Bauges. Sometimes the mountain caps, which form an extended range in front, present the appearance of a narrow ridge when seen in profile.

The mountain, called the Dent d'Alençon, near the lake of Annecy, offers a remarkable instance of this. See Plate II, fig. 6. The mass of limestone on its summit,—which I found by trigonometrical measurement to rise 3840 feet above the lake, and to be nearly 500 feet in thickness,—was undoubtedly once a continuous bed, covering the mountain like a mantle, as represented by the dotted lines: in the course of ages, the side *a a* has fallen down, and the action of rain on the soft bed, *c*, on the other side, is undermining the steep escarpment *b*, and preparing for its further destruction. The soft bed *c c*, which forms the talus or slope, being covered with vegetation on the side *b c*, is in some parts protected from rapid disintegration. On the opposite side of the valley, I found that the thick bed which formed the talus or slope under the limestone, was lias clay. I was not able to ascend the Dent d'Alençon, and therefore did not ascertain whether the bed *c* was soft sandstone or lias. In numerous instances, the upper beds of limestone in the mountains of Savoy, may be observed overlapping and overhanging, as at *a a*, Plate II, fig. 1, and are thus prepared to fall, whenever the rain and frost has widened the longitudinal natural fissures in the limestone. In Plate II, fig. 2, the mountain at *y*, which had the arched stratification, has been so broken, as to present a steep escarpment: such instances are very common in Savoy. The present state of Mont Grenier, south of Chamberry, and the vast ruins in the plain below, offer

a striking illustration of the causes which are in operation, to disintegrate the vast calcareous mountains of Savoy. The following description, with the cut, is taken from the first volume of my Travels. "A part of Mont Grenier fell down in the year 1248, and entirely buried five parishes, and the town and church of St. André. The ruins spread over an extent of about nine square miles, and are called *les Abymes de Myans.* After a lapse of so many centuries, they still present a singular scene of desolation. The catastrophe must have been most awful, when seen from the vicinity; for Mont Grenier is almost isolated, advancing into a broad plain, which extends to the valley of the Isère. It is several miles in length, and is connected with the mountains of the Grand Chartreux, but it is very narrow. Its longitudinal direction is from east to west: near the middle it makes a bend towards the north, forming a kind of bay or concavity on the southern side.

"Mont Grenier rises very abruptly upwards of 4000 feet above the plain. It is capped with an immense mass of limestone strata, not less than 600 feet in thickness, which presents on every side, the appearance of a wall. The strata dip gently to the side which fell into the plain. This mass of limestone, rests on a foundation of softer strata, probably molasse, under which are distinctly seen thin strata, alternating with soft strata. The annexed cut represents the east wing of the mountain, and a small part of the Abymes de Myans. There can be little doubt that the catastrophe was caused by the gradual erosion of the soft strata, which undermined the mass of limestone above, and projected it into the plain. It is also probable, that the part which fell, had for some time been nearly detached from the mountain, by a shrinking of the southern side, as there is at present a rent at this end, upwards of 2000 feet deep, which seems to have cut off a large section from the eastern end, that now

"Hangs in doubtful ruins round its base,"

as if prepared to renew the catastrophe of 1248. The Abymes de Myans are hills, or rather monticules, of a conical shape, varying in height from twenty to thirty feet; they cover about nine square miles: the monticules are composed of fragments of calcareous strata, some of which are of immense size. They consist of yellowish oolitic limestone, strongly resembling the lower oolites in Gloucestershire; a gray limestone, harder and more crystalline than lias, which, however, it may probably be: and a thin slaty arenaceous limestone, much resembling Stonesfield slate. Fragments of schistose chert were interstratified with some of the limestone.

"The largest masses have evidently fallen from the upper bed of limestone by which Mont Grenier is capped. The velocity

they would acquire by falling from so great a height, making due allowance for the resistance of the atmosphere, could not be less than 300 feet per second; and the projectile force they gained by striking against the base of the mountain, or against each other has spread them far into the plain. In the course of years, the rains or currents of water from dissolving snows, have furrowed channels between the larger masses of stone, and washing away part of the loose earth, have left the immense number of detached conical hills which are seen at present. So deep and vast was the mass of ruins that covered the town of St. Andrè and the other parishes, that nothing belonging to them has been discovered, except a small bronze statue."—Vol. 1, p. 201.

A part of a mountain near Servos, on the road to Chamouny, fell down in the year 1751. The fall continued for many days, and the air was darkened with immense volumes of black dust, which extended for twenty miles, and is still remembered by some of the oldest inhabitants of Chamouny. A continued succession of reports, like those of cannon, announced the successive falling of rocks, day and night. The mountain did not, like that of Mont Grenier, fall at once, for it is composed of a succession of beds of limestone resting on sandstone, and extremely fragile schist, which are even now yielding to the constant action of rain. A deep excavation, which I observed under a precipice of limestone, near the summit, appeared, in 1821, to threaten a renewal of the catastrophe of 1751.

In the Swiss Alps, the great *éboulements** which have destroyed whole villages, have been caused by the sliding down of highly inclined beds of loose conglomerates, which have been undermined at their bases. This will be better understood by a reference to Plate II, fig. 2, representing the section of a mountain on the Alps: the beds *a a b a b* are highly inclined; and should the outer bed *a* be a soft sandstone or conglomerate, the action of water-courses or heavy rains upon its foot or base, tends to destroy and undermine it, and the whole bed, perhaps several hundred feet in thickness, is suddenly precipitated into the valley. In 1806, a part of the mountain of Rosberg, between the lakes of Zug and Laworts, fell down from the cause here mentioned, and buried a considerable part of the valley, and several of the inhabitants.

Where the soil formed by the débris, or ruins from the fall of mountains, is favorable to vegetation, it becomes covered with vineyards and chestnut trees; of which we have an example in the soil that covers the former town of Pleurs, near Chavennes, and all its noble palaces, belonging to opulent citizens of Milan.

* The fall of parts of mountains is so common an occurrence in the Alps, that it is expressively called an *éboulement*, from the verb *ébouler*.—In Devonshire, and Dorsetshire, the fall of the cliffs is called a *rougement*.

On the 26th of August, 1618, "an inhabitant entered the town, and said that he saw the mountains cleaving: he was laughed at for his pains; but in the evening the mountain fell, and buried the town and all its inhabitants. The number destroyed is stated to be 2430, of whom not one escaped, except the person who warned them of their danger."

Where the soil is unfavorable to vegetation, the ruins remain exposed to the action of rains, and of torrents from the sudden melting of snow, which furrow channels through them, and leave detached monticules, as in the *Abymes de Myans;* but it is evident, that by these causes they could not be transported to distant countries, except in the comminuted form of sand or mud.

There are, however, other causes, in present activity, which tear down large masses of rock, and carry them many miles from their native sites. The mountain valleys in the higher Alps, on the confines of eternal snow, sometimes become closed by the extension of a lateral glacier across them, which dams in the water from the melting of Alpine snow, and forms a mountain lake, elevated many thousand feet above the lower habitable valleys. During very hot summers, the same cause which increases the waters in the lake, by a more rapid melting of the Alpine snows, diminishes the strength and thickness of the barrier of ice; it is rent asunder, and the whole water of the lake is suddenly precipitated into the lower valleys with tremendous violence, tearing down and bearing along with it all opposing obstacles. The water is seen approaching like a moving wall. In this manner was the village of Martigny in the Valais nearly destroyed in 1818. A similar inundation, in the valley of the Upper Doron in the Tarentaise, took place in the following year. I had an opportunity of observing its effects, which appeared to equal in intensity, but not in extent, those of diluvial action. Numerous blocks of stone, of many tons' weight, were brought down by the torrent, and scattered over a small plain at the mouth of the lateral valley, along which they had descended. These blocks were chiefly quartz rock, intermixed with a few blocks of mica and talc slate.

To proceed to the causes which are in the present time wearing down the surface of islands and continents.—The action of the sea upon the cliffs in England, proves in a striking manner the changes which this important agent can effect in the space of a few centuries, and sometimes in a few years. In Devonshire and Dorsetshire, and on the coasts of Sussex, Kent, and Suffolk, the sea has made great encroachments on the land, since the time of the Norman Conquest; as may be proved both by ancient records, and by what is now taking place; the cliffs being undermined by high tides, large portions of land are yearly falling into the sea. Notwithstanding the known loss of ground in certain situations, where the cliffs on the sea-shore are chiefly composed of sand or

soft porous beds, there is another cause in constant operation, more destructive than the direct action of the sea. Water from the land penetrates through the porous beds, and issues forth at the bottom of the cliffs, carrying with it part of the loose materials of which they are composed. In this manner, the ground is undermined, and finally sinks into the sea. In some instances, tracts of considerable extent are suddenly projected upon the beach, and acre after acre disappears. This effect of land-springs may be seen in a very striking manner in the cliffs near Cromer, and on various parts of the coast of Norfolk and Suffolk, and is still more remarkable in the cliffs near Boulogne, as the extent of the destruction of the land is well ascertained, by very ancient plans of the harbor. A lighthouse, built by order of Caligula, on a very high hill on the northeast of the harbor, and which remained entire many centuries, fell down by the destruction of the cliff in 1644; only a small part of the foundation is now visible. By a plan taken in 1550, it appears that the pharos was then at some distance from the sea. In the last two hundred years, the sea has carried away 400 metres, or nearly a quarter of a mile of land, on each side of the port. The cliffs of Boulogne I examined in 1824, and considered them as closely allied to the English Kimmeridge clay, and sand associated with it. On digging into the cliff, a few years previously, a spring of hot water issued out: probably heated by the same causes, that have formed the pseudo-volcano in the Kimmeridge clay, near Weymouth. I am informed by a friend, now at Boulogne, that during the present winter, 1837, the heavy rains in November and December had penetrated through the porous strata of the cliffs, and issued out in streamlets at their base, and thus undermined layers of clay and stone, some thousand feet in length, and 120 feet in thickness, causing the clay and stone to change their position, which was nearly horizontal, and dip in a curve to the sea at their base. In some parts the strata are broken off. He had seen the change of position from its commencement, and marked its progress from day to day. "The cause of these changes (he observes,) is as evident as the fact: it is simply the undermining of water, and of water in drops, or streamlets; for powerful streams there are none. The rain percolates through the upper porous beds, till it meets with a bed of rock or impervious clay, and then descends towards the sea, bearing with it gradually the bed along which it runs."

It may, however, be doubted, whether the surface of dry land is not gradually increasing on the whole globe. The depositions from the sea and from rivers are filling up bays, estuaries, and lakes: all broad flat valleys, and almost all low and fertile plains, were once covered with water. On the eastern side of our own island, though the land is wearing away in some parts, it is increasing more rapidly in others. The flat parts of Lincolnshire,

Cambridgeshire, and Holderness in Yorkshire, have been gained from the sea, or from rivers, by depositions of sand and mud at no very remote period; and the process is going on daily. In many parts, the sea, during high tides, is above the present level of the land, and is kept out by embankments.

In Yorkshire, the proprietors contrive to raise the surface of the ground by what is called *warping*. At the highest spring tides they open sluices in the embankments, and cover the land with the turbid sea-water, which remains until it has deposited its contents, and is let out at low water. The quantity of earthy matter, held in suspension by rivers after heavy rains, is prodigiously great. According to Major Rennell, a glass of water taken from the Ganges at the height of its inundations, yields one fourth sediment. Mr. Barrow says, in his account of China, that the quantity of mud brought down by the Yellow River was found, by calculation founded on experiment, to exceed two million solid feet per hour; and that, some miles distant from the sea, the river was three quarters of a mile broad, and was running at the rate of seven or eight miles an hour. A great part of the enormous mass of mud, which is perpetually brought down by the Yellow River, is borne by strong currents from the Yellow Sea into the Gulf of Petchelee, where the stillness of the water allows it to subside. Into the same gulf the river of Peking discharges itself, and Mr. Barrow observes, that a great part of the land adjoining this gulf, has apparently been formed, by the sand and mud brought into it: for the tide flows inland one hundred and ten miles, and often inundates the whole country, the general level of which is not more than two feet above the level of the river: indeed the deepest part of the great gulf of Petchelee, does not exceed twelve fathoms, and the prodigious number of sandy islands just appearing above the surface, are said to have been formed within the records of history.—*Barrow's China*, p. 492. From the above account, there is every probability that this wide gulf, will soon be filled up by alluvial and marine depositions. The Gulf of Mexico, according to Humboldt, is gradually filling by the sand brought into it from the Caribbean Sea on the south side, and from the vast rivers, the Rio del Norte and the Mississippi.

From several sources of information referred to in the "Asiatic Researches," and from the best accounts of the Portuguese, who first visited India, there is much reason to believe, that the whole country of Malabar, between the Gaut Mountains and the sea, has become dry land at no very remote period. Numerous traditions refer to it. There is an ancient book called "Kerul Oofpiette," or the emerging of the country of Kerul, or Malabar. The book was translated by Jonathan Duncan Esq. In this account, the formation of the land is ascribed to supernatural agen-

cy; but it contains many statements that appear highly probable. It was soon inhabited, on account of the fertility of the ground; but the inhabitants were at first driven away by the multitude of serpents, which abounded in the mud and slime of the newly emerged country. In a manuscript account of Malabar, ascribed to the Bishop of Virapli, the seat of a celebrated Roman Catholic seminary, the writer observes, that, by the accounts of the learned natives of that coast, it is little more than 2300 years since the sea came up to the foot of the Jukem or Gaut Mountain; and this he thinks extremely probable, from the nature of the soil, and the quantity of sand, oyster shells, and other fragments, met with on making excavations. It is not unreasonable to believe, that the whole coast was elevated by subterranean agency; for so recently as 1805, the bed of part of the sea and of the Indus, was permanently changed, by an earthquake near Cutch, on the coast of Bombay.

The increase of land at the mouth of the Nile, and of many European rivers, is well known. Adria, which was once a port of the Adriatic Sea, (to which it gave its name,) is now six leagues inland. In lakes, the diminution of the surface, by the gradual increase of land at the mouths of rivers which flow into them, is still more remarkable. The mud and débris brought into the lake of Geneva by the Rhone, and deposited near its entrance, has made the land advance two miles in the space of 1700 years, the Roman harbor Portus Valesiæ being now that distance from the lake. All the lakes in Savoy and Switzerland, and in our own island, are gradually diminishing by similar causes. To multiply instances of this kind would be incompatible with the limits of the present volume; every attentive observer must have noticed them in the course of his travels.

All the most fertile parts of the globe were formed by alluvial depositions: alluvial agency appears to have been the means employed, in the economy of nature, to prepare the world for the residence of social and civilized man. The most ancient cities of which we have any authentic record, Babylon, Nineveh, and Thebes, were founded in the midst of alluvial soils, deposited by the Euphrates, the Tigris, and the Nile: indeed, it does not appear unreasonable to believe, that the formation of soils, for the support of vegetables and animals, is the final end to which all terrestrial changes ultimately refer.

It has been justly observed by Dr. Paley and others, that in the peculiar conformation of the teeth in graminivorous animals, and in the production of grasses which serve them for food, we may trace evident marks of relation, and of a designing intelligent cause. With equal reason must we admit, that the destruction of mountains, and the formation of soils for the support of the vegetable tribes, are provided for, by the same intelligent cause,

and are part of a regular series of operations in the economy of nature. Hence also we may infer, that those grand revolutions of the globe, by which new mountains or continents are elevated from the deep, are parts of the same series, extending through ages of indefinite duration, and connecting all the successive phenomena of the material universe.

By a wise provision of the Author of nature, it is ordained, that those rocks which decompose rapidly, are those which form the most fertile soils; for the quality of soils depends on the nature of the rocks from which they were formed. Granitic and siliceous rocks form barren and sandy soils; argillaceous rocks form stiff clay; and calcareous rocks, when mixed with clays, form marl; but when not covered by other strata, they support a short, but nutritious vegetation. For the formation of productive soils, an intermixture of the three earths—clay, sand, and lime—is absolutely necessary. The oxide of iron appears also to be a requisite ingredient. The proportion necessary for the formation of good soil, depends much on the nature of the climate, but more on the quality of the sub-soil, and its power of retaining or absorbing moisture. This alone may make a soil barren, which upon a different sub-soil would be exceedingly productive. When this is the case, either drainage or irrigation offers the only means of permanent improvement.

Different vegetables also require different admixtures of earth. They require it, first, because it is necessary to their growth, that the soil should be sufficiently stiff and deep to keep them firm in their place; and also that it should not be too stiff; to allow the expansion and growth of their roots: and, lastly, that it should supply them with a constant quantity of water, neither too abundant nor deficient. Hence we may learn why different degrees of tenacity, depth, and power of retaining or absorbing moisture, are required in soils for different kinds of plants. Thus, in uncultivated countries, we find that certain vegetables affect particular situations, in which they flourish spontaneously and exclusively; and it is only by imitating nature, and profiting by the instruction she affords, that we can hope to obtain advantageous results, or acquire certain fixed principles, to guide us in our attempts to bring barren lands into a state of profitable cultivation. When rocks contain in their composition a due proportion of silex, clay, and lime, they furnish soils whose fertility may be said to be permanent. The most fertile districts in England were made so by nature; their original fertility was independent of human operation.

Some small portion of the earths and alkalies is found by chemical analysis in plants; but it would be contrary to fact and analogy to suppose, that the earths, in a concrete state, form any part of the food of plants; the earths and alkalies which they contain,

are in all probability formed from more simple elements, by the process of vegetation; for it is now ascertained, that the earths and alkalies are compound substances.

The principal elements found in plants are hydrogen, carbon, and oxygen, and by experiments of Gay Lussac and Thenard* it appears, that the hydrogen and oxygen in starch, gum, vegetable oils, and sugar, exist in precisely the same proportions that form water. Carbon, the other principal elementary substance found in plants, exists both in water and in the atmosphere. Water and the atmosphere contain in themselves, or in solution, all the elements necessary for the support and growth of vegetables. But most soils are either too wet or too dry, too loose or too adhesive, to admit plants to extract these elements, in the proportions necessary for their growth. Manures supply this deficiency, by furnishing in great abundance the hydrogen, carbon, or azote, which they may require. In proportion as soils possess a due degree of tenacity, and power of retaining or absorbing heat and moisture, the necessity for a supply of manure is diminished; and in some instances, the earths are so fortunately combined, as to render all supply of artificial manure unnecessary. He who possesses on his estate the three earths,—clay, sand, and lime,—of a good quality, with facilities for drainage or irrigation, has all the materials for permanent improvement; the grand desiderata in agriculture being to render wet lands dry, to supply dry lands with sufficient moisture, to make adhesive soils loose, and loose soils sufficiently adhesive.

The intermixture of soils, where one kind of earth is either redundant or deficient, is practiced in some countries with great advantage. Part of Lancashire is situated on the red sandstone described in the twelfth chapter. This rock, being principally composed of siliceous earth and the oxide of iron, forms of itself very unproductive land: but, fortunately, in many situations, it contains detached beds of calcareous marl near the surface. By an intermixture of this marl with the soil, it is converted into fertile land, and the necessity for manure is superseded. The effect of a good marl applied liberally to this land, lasts for more than twenty years. In some lands a mixture of light marl, which contains scarcely a trace of calcareous earth, is found of great service. The good effect of this, appears to depend on its giving to the sandy soil a sufficient degree of tenacity. The sterile and gravelly soils in Wiltshire have been recently rendered productive, by mixing them with chalk: the most liberal application of manure having been found ineffective, or injurious. In stiff clay soils, where lime is at a great distance, the land might frequently be improved, by an intermixture with siliceous sand. A proper

* Recherches Physico-Chimiques.

knowledge of the quality of the sub-soil, and the position of the sub-strata, is necessary to ascertain the capability of improvement which land may possess. It may frequently happen, that a valuable stratum of marl or stone, which lies at a great depth in one situation, may rise near the surface in an adjoining part of the estate, and might be procured with little expense.

Lime is the only earth which has been generally used to intermix with soils, and has been considered as a manure; but its operation as such is very imperfectly understood. Burnt lime, when caustic, destroys undecomposed vegetable matter, and reduces it to mould; so far its use is intelligible. It combines also with vegetable or mineral acids in the soil, which might be injurious to vegetation; here its operation is likewise intelligible: but if we assert, that when burnt lime has absorbed carbonic acid and become mild, it gives out its carbon again to the roots of plants, we assume a fact, which we have neither experiments nor analogies to support. The utility of lime in decomposing vegetable matter and neutralizing acids is obvious: but its other uses are not so evident; except we admit that it acts mechanically on the soil, and renders the clay or sand with which it is intermixed, better suited to the proper expansion of the roots, and more disposed to modify the power of retaining or absorbing the requisite degree of heat and moisture, which particular vegetables may demand.

Where earths are properly intermixed, instances are known of land producing a succession of good crops for many years without fallowing or manure. On the summit of Breedon Hill, in Leicestershire, I have seen a luxuriant crop of barley growing on land, that had borne a succession of twenty preceding crops without manuring. This is more deserving notice, being in an exposed and elevated situation, and upon the very hill of magnesian limestone, which has been so frequently referred to by chemical writers, as peculiarly unfavorable to vegetation. The limestone of this hill contains above 20 per cent. of magnesia.*

The temperature requisite for the growth of plants is influenced by the power of different soils to absorb and retain heat from the solar rays, which depends much on their moisture and tenacity. "It is a well known fact, that the vegetation of perennial grasses in the spring, is at least a fortnight sooner on limestone and sandy soils, if not extremely barren, than on clayey, or even in deep rich soils: it is equally true, but perhaps not so well known, that the difference is more than reversed in the autumn."†

* The magnesian lime acts more powerfully in destroying undecomposed vegetable matter than common lime, and its effects on land are more durable: hence it is in reality of greater value in agriculture, as a much smaller quantity will answer the same purpose.

† Observations on Mildew, by J. Egremont, Esq.

This effect Mr. Egremont ascribes, with much probability, to the rich or clayey soils absorbing heat slowly, and parting with it again more reluctantly than the calcareous soils, owing to the greater quantity of moisture in the clay, which is an imperfect conductor of heat.

Calcareous soils might frequently be much improved by a mixture of clay, sand, or gravel, which, in many situations, is practicable with little expense, and would well reward the labor of the experimental agriculturist.

Calcareous Tufa.—Beside the new land formed by alluvial depositions, beds of calcareous tufa are sometimes formed in valleys, and at the bottom of lakes, by a process which bears some analogy to chemical formations. Springs, containing carbonic acid, that issue from limestone strata, contain particles of carbonate of lime chemically dissolved in the water; but on exposure to air and light, the carbonic acid, which had but a slight affinity for the particles of limestone, separates, and the particles of lime are precipitated and form calcareous incrustations: these in a course of years compose thick beds, and are sometimes sufficiently hard to be used for building stone. The Rock Mill, near Stroud, in Gloucestershire, is built of this stone. In almost all limestone countries, there are instances of calcareous incrustations formed in springs, which have received the name of petrifying wells.

Thermal waters, that contain calcareous earth in solution, deposit beds of tufa very rapidly. Nearly the whole bottom of the valley at Matlock Baths, in Derbyshire, is filled with calcareous tufa, forming a bed not less than fifty feet in thickness, and half a mile in length. It contains fragments of moss, and some land shells. The horns of a stag were found in excavating this tufa; it is deposited by the thermal springs, that every where gush out from the hill behind the baths. Except the depositions from thermal waters, beds of calcareous tufa are seldom formed on land of any considerable magnitude; but thermal waters have probably been important agents in the formation of many of the secondary strata at the bottom of the ocean. (See Chapter XVI.)

Mr. Lyell, in the first volume of his "Principles of Geology," has described many depositions of calcareous tufa in the volcanic districts of France and Italy.

Depositions of fresh-water limestone are slowly forming in some of our present lakes. Mr. Lyell, in "Geological Transactions," 1826, describes a formation of this limestone about nine miles west of Forfar, in Scotland, at the bottom of a small lake which has been in a great part excavated for marl. It contains different strata, of variable thickness, of shell and rock marl. The rock marl consists wholly of carbonate of lime; it is hard and compact, and in some parts crystalline. The lower shell

marl rarely contains any distinguishable quantity of shelly matter. In the rock marl are found shells of Helices, the Turbo fontinalis, and the Patella lacustris. There are remains of land quadrupeds in the shell marl, but not in the rock marl.

Peat is a substance which has been classed with alluvial soils, though it is obviously a vegetable production. Peat formerly covered extensive tracts in England, but is disappearing before the genius of agricultural improvement, which has no where produced more important effects, than in the conversion of the black aud barren peat moors of the northern counties, into valuable land covered with luxuriant herbage, and depastured by numerous flocks.

"In describing the general appearance of a peat moor, (says Mr. Jameson,) we may conceive an almost entire flat of several miles extent, of a brown color, here and there marked with tufts of heather, which have taken root, owing to the more complete decomposition of the surface peat; no tree or shrub is to be seen; not a spot of grass to relieve the eye in wandering over this dreary scene. A nearer examination discovers a wet spongy surface, passable only in the driest seasons, or when all nature is locked in frost. The surface is frequently covered with a slimy, black-colored substance, which is the peat earth so mixed with water, as to render the moor only passable by leaping from one tuft of heather to another.

"Peat is found in various situations, often in valleys or plains, where it forms very extensive deep beds, from three to forty feet deep, as those in Aberdeenshire: it also occurs upon the sides of mountains, but even there it is generally in a horizontal situation. The tops of mountains, upwards of two thousand feet high, in the Highlands of Scotland, are covered with peat of an excellent kind.

"It is also found in situations nearly upon a level with the sea: thus, the great moss of Cree, in Galloway, lies close upon the sea, on a bed of clay, little higher than the flood marks at spring tides."*

In the first volume of Dr. MacCulloch's valuable "History of the Western Islands of Scotland," he has enumerated nearly forty plants which concur to the generation of peat, of which the most abundant is the sphagnum palustre. The process by which these vegetables are converted into peat, is most clearly seen in the sphagnum. As the lower extremity of the plant dies, the upper sends forth fresh roots like most of the mosses, the individual thus becoming in a manner immortal, and supplying a perpetual fund of decomposing vegetable matter. A similar process, though less distinct, takes place in many of the rushes and grasses, the

* Jameson's Mineralogy of the Shetland Islands.

ancient roots dying together with the outer leaves, while an annual renovation of both, perpetuates the existence of the plant. The growth of peat necessarily keeps pace with that of the vegetables from which it is formed; hence the necessity of replacing the living turf on the bog where peat has been cut,—a condition now required in all leases, in which liberty to cut turf is included. On the conversion of vegetable matter into peat, Dr. MacCulloch observes:—"Where the living plant is still in contact with peat, the roots of the rushes, and ligneous vegetables, are found vacillating between life and death, in a spongy, half decomposed mass. Lower down, the pulverized carbonaceous matter is seen mixed with similar fibres, still resisting decomposition. These gradually disappear, and at length a finely powdered substance alone is found, the process being completed by the total destruction of all the organized bodies."—p. 130. The best peat is that of which the decomposition is most complete, and the specific gravity and compactness the greatest. The quality of peat, Dr. MacCulloch observes, is much affected by the wetness or dryness of the soil, and the elevation, or other causes, which influence the temperature and moisture of the atmosphere. It is only in the first stages of decomposition that peat is soluble, and communicates a dark color to water.

The rapid formation of peat in many situations, where it is found covering ground that was formerly pastured, admits of an easy explanation, since Dr. MacCulloch has so clearly described the mode in which this substance is generated.

The property possessed by peat of preserving animal matter from putrefaction, is well deserving notice. It is probably owing to this, that some of the fleshy parts of the mastodon have been so long preserved in peat bogs.

In the *Philosophical Transactions*, 1734, there is a letter from Dr. Balguy, giving an account of the preservation of two human bodies in peat for fifty nine years. On January 14, 1675, a farmer and his maid servant were crossing the peat moors above Hope, near Castleton, in Derbyshire; they were overtaken by a great fall of snow, and both perished: their bodies were not found till the 3d of May, in the same year; and being then offensive, the coroner ordered them to be buried on the spot in the peat. They lay undisturbed twenty eight years and nine months, when the curiosity of some countrymen induced them to open their graves. The bodies appeared quite fresh, the skin was fair and of its natural color, and the flesh as soft as that of persons newly dead. They were afterwards frequently exposed as curiosities until in the year 1716, when they were buried by order of the man's descendants. At that time Dr. Bourne, of Chesterfield, who examined the bodies, says the man was perfect, his beard was strong, the hair of his head was short, and his skin hard and

of a tanned leather color, like the liquor he was lying in. The body of the woman was more injured, having been more frequently exposed; the hair was like that of a living person. Mr. Wormwald, the minister of Hope, was present when they were removed: the man's legs, which had never before been uncovered, were quite fair when the stockings were drawn off, and the joints played freely without the least stiffness."

In the beginning of the last century, the perfect body of a man, in the ancient Saxon costume, was discovered in peat, at Hatfield Chase in Yorkshire: it soon perished on exposure to the air.

Extensive tracts of cultivated ground are sometimes converted into sandy deserts, by the drifting of sea-sand inland. The process by which this is effected, is taking place, at present, in many situations. During very high winds, the sand is driven from the sea-shore to a certain distance, leaving an elevated ridge at the further boundary of the drift. Succeeding winds blow the sand forward, and at the same time bring fresh sand from the shore to supply its place. In the sixth volume of the *Transactions of the Irish Academy*, an account is given of the encroachment of the sand, over some parts of Ireland. Trees, houses, and even villages, have been surrounded or covered with sand, during the last century. In the vicinity of sandy deserts, the sand is also encroaching on the habitable land. The loose sands of Libya are thus spreading over the valley that borders the Nile, and burying the monuments of art and the vestiges of former cultivation. From a similar cause, the country immediately around Palmyra, that once supplied a crowded population with food, now scarcely affords a few withered plants, to the camel of the wandering Arab.

A sandy inundation, on the north coast of Cornwall, was mentioned Chap. I, p. 15. This sand, which is composed of fragments of shells and coral, is in some parts cemented into sandstone, by water infiltrating from the slate rocks: it is similar in appearance to the recent sandstone of Guadaloupe, in which human skeletons have been found: the latter is a very common sandstone in the West Indies; it increases rapidly, and the land gained from the sea, which forms some of the plains of St. Domingo, is composed of it. A concreted calcareous sandstone, extends on the southern, western, and northwestern coast of Australia, for three thousand miles.

Among the causes in present activity, which are changing the surface of the globe, the labors of coralline polypi must not be unnoticed. These polypi raise up walls and reefs of coral rock with astonishing rapidity in tropical climates, and encircle the present islands with belts of coral, thus enlarging their coasts. A coral reef of seven hundred miles in length, extends from the northwest of Australia towards New Guinea. For a detailed

account of coral rocks and reefs, I must refer the reader to the observations of Dr. Forster, and the voyages of Captain Flinders and of Kotzebue, and of the French naturalists MM. Quoi and Gaimard, but more particularly to the observations of Captain Beechy, made during his voyage to the Southern Pacific. The subject of coral reefs has already been referred to, pp. 82 and 83, Chap. VI.

The lamelliform polypi, that possess the power of secreting lime in such vast abundance, as to form beds that rival in magnitude and extent the greatest calcareous beds of our present continents, are denominated by naturalists madrepora astrea, caryophillia, meandrina (commonly called brain-stone,) and millepora, &c. The calcareous habitations of these animals remain permanent, and after one generation has perished, another constructs similar cells upon the former ones, until they rise to the surface of the sea. It has been ascertained, that many of the encircling coral reefs, which have a lake within them, have been constructed on the summits of the numerous volcanic craters that have been raised in the Pacific Ocean, and are still forming there. Other coral reefs encircle islands at the distance of two or three miles from the shore. Coral reefs of great length, like that between the northwest of Australia and New Guinea, are probably formed upon long submarine chains of mountains, that rise nearly to the surface of the ocean. Mr. Darwin, who has recently observed many of the coral reefs in the Pacific Ocean, is inclined to believe, that some of the largest are constructed on the surface of extensive islands that have been gradually submerged below the surface of the sea. He founds this opinion chiefly on the vast circumference of these reefs, which he supposes to exceed that of any volcanic craters: but according to Von Buch, a volcanic crater was formed at St. Miguel, one of the Azores, soon after the first discovery of that island, fifteen English miles in circumference.—*Edin. New Phil. Journal, Oct.* 1836, p. 203. We have no reason to conclude, that volcanic craters of far greater magnitude may not occur. Mr. Darwin is, however, inclined to the opinion, that the process of elevation and submergence of extensive tracts, is taking place along parallel lines in the Pacific Ocean, which may eventually form a new continent.*—*Proceedings of the Geological Society of London*, 1837.

Organic Remains in Diluvial Beds.—As the fossil remains of the mastodon, the elephant, the rhinoceros, and hippopotamus occur with the bones of other mammalia in diluvial beds, this circumstance proves the great antiquity of these beds, and distinguishes them from recent alluvial depositions. The grinders of the elephant, the rhinoceros, and hippopotamus, are frequently

* The animals that form coral reefs are represented in Buckland B. T. vol. 2, pl. 54; see also his Observations, pp. 442 to 449, vol. 1.

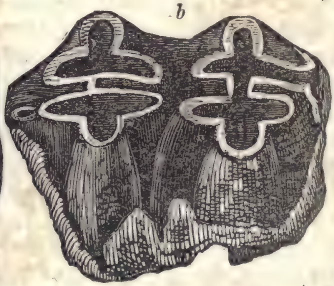
found in diluvial beds in England, and in the Crag; see Chap. XVIII. Those of the mastodon are very rare. A tooth of one species of mastodon found in Europe is represented in p. 269. The teeth most commonly found in diluvial beds are those in the annexed cuts. The tusks of the elephant are sometimes found entire; those of the rhinoceros and hippopotamus are occasionally discovered.

The first figure represents the pointed tooth of the mastodon; the other the flat crowned tooth of the elephant, which is sometimes larger than that of the mastodon.

The following cut represents the molar tooth of the rhinoceros, *a*, from Kirkdale cavern; *b* is the molar tooth of the hippopotamus, much worn, from the same locality.*

a

b



The fossil elephant, or mammoth, is the most remarkable of the ancient herbivorous quadrupeds, both from its vast size, and the amazing number of bones of this genus, which are found in the northern parts of Europe, and in America. The mammoth

* Many of the bones of extinct species found in diluvium, appear to be of the same epoch as those of similar animals in caverns, and some of the tertiary beds.

must have existed in herds of hundreds and thousands. According to Pallas, there is scarcely a river, from the Don or the Tanais, to the extremity of the promontory Tchuskoinosa, in the banks of which the bones of the mammoth are not abundant. There are two large islands near the mouth of the river Indigerska, which are said to be entirely composed of the bones of the mammoth, intermixed with ice and sand: the tusks are so perfect, that they are dug out for ivory. With the bones of the mammoth are intermixed those of the elk, the rhinoceros, and other large quadrupeds. The body of a fossil elephant has been found entire, with the flesh preserved, buried in ice: it had a mane along its back, and was covered with coarse red wool, protected by a hair of a coarser kind, indicating that it was an inhabitant of cold or temperate climates; indeed, the circumstance of the body being preserved in ice, is a further proof of this; for had it been conveyed from distant regions, the flesh must have been speedily decomposed, before it could have been enveloped in ice. The height of this animal was from fifteen to eighteen feet. Bones and teeth of the mammoth are not unfrequently found in England, in beds of diluvial gravel and clay, and in caverns; they are chiefly found in low situations, such as the vale of the Thames, and the vale of the Severn. The mammoth bears a near resemblance to the Indian elephant, but Cuvier regards it as a distinct species.

The rhinoceros, of which there are three large species, and one smaller, appears to have lived with the fossil elephant: their bones are found together; but it is in Siberia that the bones of the rhinoceros are most numerous, and best preserved. In the year 1771, the entire body of one of these animals was found in the frozen sands of that country.

Bones and teeth of the hippopotamus are found both in England, France, Germany, and Italy: there are two species; the largest resembles the African hippopotamus, the smaller is the size of the wild boar. Bones and teeth of the large animal, called the mastodon, are found both in Europe and America. The great mastodon had pointed grinders; it was a native of North America, and equaled in size the elephant, which, in many particulars, it resembled. Entire skeletons of the mastodon have been found in salt marshes; but what is more extraordinary, parts of the flesh and the stomach have been found with them. Among the vegetable substances in the stomach, were distinguished the remains of some plants known in Virginia. The Indians believe that this animal is still living north of the Missouri, and the above circumstances render it probable, that this species of mastodon has not been long extinct. Bones of other species of the mastodon are found in Europe and South America; these are probably more ancient. Teeth of a gigantic species of tapir have been found in France and Germany: the bones of horses are also found

in great abundance, with the bones of the above mentioned animals. Bones and horns of the elk, the stag, and of various species of deer, and of oxen, some of which closely resemble existing species, are often intermixed with the bones of elephants, and other ancient animals. With these animal remains, are also found the bones of carnivorous animals of the size of the lion, the tiger, and the hyena; the bones of bears are numerous, particularly in caverns.

The number of bones belonging to the order of pachydermata, and of ruminant, and carnivorous quadrupeds, is so great in various parts of Europe, as to leave no doubt that the animals were inhabitants of northern or temperate climates. In America have been found the bones of two large animals of extraordinary form. The megatherium is the size of the rhinoceros; it unites part of the structure of the armadillo with that of the sloth; its claws are of vast length and size. The megalonyx was nearly similar in form, but smaller. For a description of the structure of the megatherium, see Buckland's B. T. vol. 1, and the plates 5 and 6, vol. 2.

Bones of the camel have been occasionally found in some parts of Europe, but they are of rare occurrence. For a knowledge of nearly all the above species of fossil mammiferous quadrupeds, we are indebted to the researches of Cuvier. "Their bones," he observes, "are found in that mass of earth, sand, and mud, that diluvium which covers our large plains, fills our caverns, and chokes up the fissures in many of our rocks. They incontestably formed the population of the continents, at the epoch of the great catastrophe which has destroyed their races, and has prepared the soil on which the animals of the present day subsist. Whatever resemblance certain of these species bear to those of existing species, the general mass of this population had a different character; the greater part of the races which composed it have been utterly destroyed. Among all these mammiferous animals, the greater number of which have their congeners living at the present day, there has not been found a single bone or tooth of any species of ape or monkey.* Nor is there any trace of man: all the human bones which have been found, along with those of which we have been speaking, have occurred accidentally; and their number, besides, is exceedingly small, which assuredly would not have been the case, if men had been then settled in the countries which these animals inhabited."†

---

* A single exception to this statement has recently been discovered in tertiary freshwater strata in the south of France. At the base of the Pyrenees, amidst a prodigious number of the bones of fossil mammalia, was found the lower jaw of an ape, belonging to an individual about 30 inches high.

† For an account of human bones found in caverns, mixed with the bones of extinct species, see the preceding chapter.

The animals whose bones are found in peat bogs and marshes, may, I conceive, be referred with much probability, to a more recent epoch than that in which the diluvial beds were deposited. Skeletons, both of the Irish elk and the great American mastodon, have been found erect in peat bogs and marshes, which prove that the surface of the ground has undergone little change since the animals perished. The further circumstance of the flesh and stomach of the mastodon being found near the surface, not protected, like the bodies of the elephant and rhinoceros found in Siberia, by ice, seems opposed to the general belief in the high antiquity of these animal remains, and it is admitted by Cuvier, that they are in better preservation than any other fossil bones. The quadrupeds whose bones are buried in beds of clay, sand, or gravel, or accumulated in caverns, undoubtedly lived in a very remote period, and under a different condition of our planet to the present one. The northern parts of Europe seem now incapable of supporting the immense number of elephants, which have formerly spread over all the valleys bordering the Frozen Ocean. Were we to admit that the temperature of the earth was then higher than at present, which the remains of palms and other tropical plants found in northern latitudes render highly probable, this would not remove the difficulty; for the fact that entire bodies of elephants have been preserved in ice, and that their skins were covered with a thick coat of wool and hair, proves that these animals were constituted for living in cold climates, and that their remains have not been transported to any great distance from the countries which they inhabited.*

The remains of these large quadrupeds occur in different states of preservation. In the frozen regions of the north the ivory of the tusks is perfect. In beds of clay, the bones and teeth are frequently impregnated with mineral matter; but in gravel, they are generally in a loose or friable state, or at least they soon become so, after exposure to the air. In the *Phil. Journal of Edinburgh*, January, 1828, an account is given of numerous bones of the mastodon, rhinoceros, and other animals, having been found on the surface of the ground near Irrawady River, in Ava. These bones, though exposed to the atmosphere, are stated to be extremely hard; they were mixed with silicified wood, in a deposition of sand or gravel. With the remains of the broad-toothed mastodon, were also found teeth of a new species of mastodon of enormous size, which appears to be intermediate in form, between that of the elephant and of the mastodon: it has hence re-

* A friend has suggested, that the Siberian elephants were probably migratory, and passed the winter months in more temperate latitudes. If this were the case, individuals, that from lameness or disease were unable to travel, may have been incrusted with ice immediately after death.

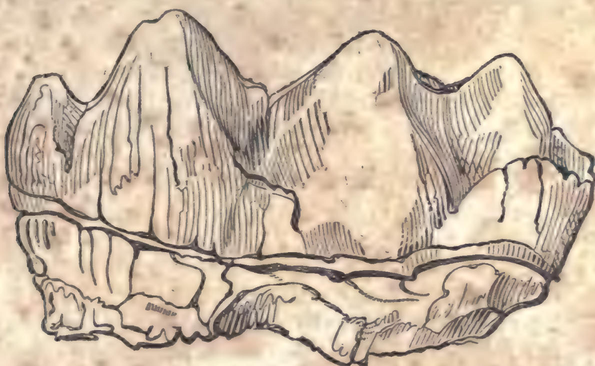
ceived the name of *mastodon elephantoides.* Specimens of these teeth are in the museum of the Geological Society in London.

Many interesting discoveries of new forms of organized beings will probably be made among the fossil remains in Asia. The skeleton of a very extraordinary mammalian animal, as large as the rhinoceros, has lately been found by Captain Bentley, in the Sivalic or Sub-Himmalayan range of hills, and hence has been denominated the *sivatherium.* It had horns and a trunk, uniting in some degree the characters of ruminant animals like the ox, and and those of the order pachydernata, like the elephant and tapir. Remains of the mastodon, the elephant, and the hippopotamus, with those of ruminant animals, were found with those of the sivatherium.

The remains of the gigantic tapir, said to have been found in France and Germany, are now supposed to belong to a remarkable animal called the *Dinotherium*, the largest of terrestrial mammalia. The above cut represents the crown of the tooth of this animal, of the natural size ; it is described by Baron Cuvier in the second volume of his *Ossemens Fossiles*, under the head of the Gigantic Tapir, and mentioned as being in my possession. It was found with other mammalian remains near Grenoble. From the hardness and brilliance of the enamel, it appears as fresh as if recent, and is the most perfect fossil tooth I have ever seen.

Annexed is a profile of the side of the tooth, which shows that the roots are broken off, but the tooth itself is quite perfect, and

not in the least water-worn. The two drawings of the tooth are given, because the figure of it in Cuvier's *Ossemens Fossiles* is so inaccurate, that it conveys no proper idea of its form. Models of this tooth were sent from Paris to all the principal museums on the continent. It belonged to the late Faujas St. Fond, and was purchased by me when his museum was sold in 1819. There were, from the same locality, teeth of the mastodon, the small hippopotamus, and the rhinoceros, which I also purchased. The tooth of the mastodon was considerably water-worn, but the projecting points, on the crown of the tooth, converge in a similar manner to those of the tooth of the mastodon from the Crag, of which a drawing was given in Loudon's Magazine of Natural History, 1836. For an account of the Dinotherium, consult Dr. Buckland, B. T. Vol. I. and II., and the supplementary notes and plate.



CHAPTER XXIII.

ON THE ELEVATION OF MOUNTAINS AND CONTINENTS.

The Elevation of the Beds of Granite and Slate in England proved by the Author, in 1823, to have taken place at a much earlier Epoch, than the Elevation of the Granite of Mont Blanc.—The Facts on which this Conclusion was founded described and explained.—Application of similar Conclusions to other Mountain Ranges by M. Elie de Beaumont.—The elevation of Continents probably effected by a distinct Cause from that which elevated Mountain Ranges.—Axis of Elevation in Mountain Ranges.—Instances of the Elevation and Submergence of the Earth's Surface in various Parts of the World.

THAT granite, or some modification of granite, forms the foundation rock of the present continents, is admitted by geologists. It is also ascertained, that specimens of granite, gneiss, and mica slate, from the most distant parts of the globe, appear to be identical. It is, therefore, probable that the crust of granite which environs the globe, was formed or consolidated at the same epoch, though local protrusions of granite have taken place at much later epochs.

If granite be the lowest and most extensive formation of known rocks, yet, in many countries, it is raised in immense ridges, forming the basis of mountain ranges: sometimes the beds of granite are nearly vertical, and constitute the summit as well as the central base of mountains. An inquiry suggests itself; was the elevation of these mountain ranges contemporaneous in different countries? The followers of Werner maintained, that granite mountains were crystalline masses, precipitated in a universal ocean, impregnated with mineral matter; and that their elevation was coëval with their origin. In the year 1819, M. Daubuisson, published his *Traité de Géognosie*, in which, following the steps of Werner on most points, he asserted that the granite of the Alps attained its present elevation soon after the epoch of its formation. In the years 1820, 1821, and 1822, I had frequent opportunities of ascertaining that the beds of granite were not elevated, till after the deposition of the calcareous beds that rest upon them. I farther ascertained, that many of these calcareous beds were identical with the upper secondary strata in England; hence it followed, that the granite beds in the Alps were not elevated till a late geological epoch, after the deposition of the oolites and chalk. This discovery I published in 1823, in my Travels in the Tarantaise, vol. ii, pp. 17, 18; and I there distinctly stated, *that the elevation of the granite of the Alps, was more recent, than the elevation of the beds of granite and slate in England.* Neither the importance of the discovery, nor its now generally admitted truth,

have obtained for it the attention which I think it was justly entitled to, and which it would certainly have received, had it been announced, by any tyro in geology, either in France or Germany. At pages 182 and 183 of the present volume will be found a brief account of this discovery, which was also republished in 1828; but it may be proper to give a more full reference to the sections by which the discovery was illustrated, as they serve, not only to explain from what data the relative age of the elevation of different mountain chains may be ascertained, but to show that M. Elie de Beaumont has been guided by exactly the same data, in forming his recent conclusions, respecting the ages of mountain chains in various parts of Europe.

The facts that determine the geological ages of the elevation of mountain ranges, are the following:

1*st.* *If a series of strata of different ages rise together conformably or nearly at the same angle, the epoch or period of their elevation was subsequent to the deposition of the most recent or outermost beds.*

Thus in the section Pl. II, fig. 2, *d d d*, the highly inclined beds of granite, and primary rocks on Mont Blanc and its vicinity, are covered on their flanks with the secondary formations, *c c*, *b a b*, rising at nearly the same angle, and as these secondary formations are similar to the lias, oolites and green sand, of the strata, we may safely infer, that the elevation did not take place, till after the deposition of the outermost bed *a*, which is similar to the green sand of the chalk formation.

2*d.* *If elevated beds of ancient granitic formations, are partly covered with nearly horizontal beds of secondary or more recent strata, the elevation of the beds of granite, &c. took place at an epoch prior to the formation of the beds which rest unconformably on the ancient rocks.*

The section of Charnwood Forest, Pl. II, fig. 4, offers an illustration of the latter case. The beds of granite and slate rocks, *b b* and *c c*, that rise at a highly inclined angle, are covered by horizontal secondary beds of new red sandstone, *a a a:* hence we are certain, that the elevation of the lower or more ancient beds, took place at an earlier epoch than the deposition of the beds *a a*.

Now if we admit, that similar secondary formations in different parts of Europe, were deposited at the same epoch, we must admit also, that the elevation of the beds of slate and granite in Charnwood Forest, was long prior to the elevation of the granite of Mont Blanc. Or, in other words, the beds of granite at Charnwood, were tilted up before the formation of the new red sandstone; but the beds of granite in Mont Blanc were not elevated before the deposition of the green sand.

It would scarcely be possible within the limits allowed for the subject in the present volume, to give a more clear and concise

account of M. Elie de Beaumont's views, than by quoting Professor Sedgwick's summary, in his able and truly eloquent address to the Geological Society in 1831. After which, I shall notice some corrections M. Elie de Beaumont has since found necessary to introduce.

"By an incredible number of well conducted observations of his own, combined with the best attested facts recorded by other observers, M. Elie de Beaumont has proved, that whole mountain chains have been elevated at one geological period,—that great physical regions have partaken of the same movement at the same time,—and that these paroxysms of elevatory force, have come into action at many successive periods.

"Step by step we have been advancing towards the conclusion —that different mountain chains had been elevated at several distinct geological periods; and by a long series of independent observations, Humboldt, Von Buch, and other great physical geographers, had proved,—that the mountain chains of Europe might be separated into three or four distinct systems; distinguished from each other (if I may so express myself) by a particular physiognomy, and above all, by the different angles made by the bearings of their component formations, with any assumed meridian. All the subordinate parts of any one system were shown to be parallel; while the different systems *(mountain ranges)* were inclined at various angles to each other.

"By an unlooked for and most felicitous generalization, M. Elie de Beaumont has now proved, that these two great classes of facts are commensurate to each other; and that each of these great systems of mountain chains, marked on the map of Europe by given parallel lines of direction, has also a given period of elevation, limited and defined by direct geological observations."

Professor Sedgwick then describes four of these systems or mountain chains. "The first includes the higher elevations in eastern France, of the Côte d'Or, and Mount Pilas, and a portion of the Jura chain; it may also be traced in the chain of the Erzgebirge, between Bohemia and Saxony. This system or mountain chain, never rises into mountains of the first order, but is marked throughout by many longitudinal ridges and furrows, ranging nearly parallel to each other, in a direction about northeast and southwest. It will appear that this chain has been elevated, after the deposition of the oolitic series, but before that of the chalk formation, for the lower secondary formations, comprising the oolites, wherever they appear, are elevated in broken or contorted strata, yet they preserve a parallelism in the general direction of the ridges. On the contrary, wherever beds analogous to chalk or green sand occur, they are found at a dead level, and expand in horizontal planes into the neighboring mountains, like the sea at the base of a lofty cliff; or if they have undergone any

movement, it is shown to have no relation to the bearing of the older ridges and to have been produced at a later period. Hence it follows, that the action of elevation was violent, and of short continuance, for the inclined strata are shattered and contorted, and between them and the horizontal strata, there is no intermediate gradation of deposits: it farther proves, that the period of elevation was followed by an immediate change in many of the forms of organic life."

"The next great system includes the whole chain of the Pyrenees,—the northern Apennines,—the calcareous chains to the northeast of the Adriatic,—nearly the whole of the Carpathian chain, and it extends thence through the Hartz mountains, to the plains of northern Germany. Through the whole of these vast regions, the main bearings of the beds range about west northwest and east southeast. This system was elevated at a later period than the former, and not till the chalk and green sand had been deposited, for the strata of these formations are every where ruptured and contorted, and often lifted up to the very pinnacles of the mountains: whereas, when any of the tertiary strata approach these ranges, they are stated to be in a position nearly horizontal, as was the surface of the waters in which they were deposited, unless disturbed by local causes. Hence, it is inferred, that the great parallel ridges and chains of this second system were suddenly and violently elevated, at a period between the deposition of the chalk, and the commencement of the tertiary groups. The corresponding change in organic remains, is still more striking than in the former system."

"The third system embraces a great number of parallel ranges, bearing about north northeast, and west southwest; it includes the whole western Alps, from the neighborhood of Marseilles, to the volcanic ridges near the lake of Constance. It is attempted to be proved, that all these parallel ranges in the western Alps, had their origin after the tertiary molasse, a deposit partaking of all the elevations and contortions of the older strata; that the elevatory movements were sudden and violent, and commenced at a time when tribes of mammalia flourished in many parts of Europe; and that these movements were immediately succeeded by great horizontal deposits of old diluvial gravel at the base of the western Alps, and probably, also, by that vast offshot of Scandinavian rocks, which lie scattered over the plains of Germany."

"The fourth system embraces several considerable chains in Provence, and nearly the whole chain of the eastern Alps, from the great flexure, in the region of Mont Blanc, to the Alps of the States of Austria. The range extends E. N. E. and W. S. W. M. Elie de Beaumont appears to have proved, that there are two distinct deposits of diluvial gravel, near a portion of the western Alps: that the colossal mass of Mont Blanc, and at least a con-

siderable portion of the eastern Alps, were elevated after the deposit of the older diluvium; and that all the newer diluvium, including the granite blocks scattered over Savoy, rolled off from the regions of the higher Alps, during this last period of their elevation. There are six other supposed periods of elevation. If these generalizations be true, and they seem to be based on an immovable mass of evidence, we must conclude that there have been, in the history of the earth, long periods of comparative repose, during which the sedimentary deposits went on in regular continuity; and short periods of comparative violence and revolution, during which that continuity was broken; and if we admit that the higher regions of the globe have been raised from the sea by any modification of volcanic force, we must then also admit, that there have been several successive periods of extraordinary volcanic energy. How we are to escape from this conclusion, I am unable to comprehend, unless we shut out the evidence of our senses."

"That the system of M. Elie de Beaumont is directly opposed to a fundamental principle of Mr. Lyell, cannot admit of a doubt; and I have decided in favor of the former author, because his conclusions are not based upon any *à priori* reasoning, but on the evidence of facts."*

If we admit that the primary, the transition, the secondary, and the tertiary classes of rock, were formed at different successive epochs, and that the lower beds in each of these classes, are more ancient than the beds which rest upon them, it follows, as a necessary consequence, that the elevation of any of these rocks must be dated from a later epoch than the period of their formation. The elevation of a range of primary or transition mountains, if they are not covered by any secondary or tertiary formations, may indeed be dated either from an epoch coeval with their consolidation, or from any subsequent epoch; but if they are partly covered by secondary or tertiary beds which are tilted up with them, we have direct evidence that the date of their elevation was posterior to the secondary or tertiary epoch. So far we may advance on secure ground; but when we infer that mountains which range in the same direction were all elevated at the same time, we wander into the region of hypothesis. It is by no means certain that the elevation of the outer ranges of the Alps was contemporaneous with that of the principal range. In various parts of Savoy, I observed that the mountains at a certain distance from the central range, had their escarpments turned in a different

* Though I agree with Professor Sedgwick and M. Elie de Beaumont, that the elevation of mountain ranges, where the beds are nearly vertical, was effected by a sudden and violent upheaving, yet I am persuaded that the elevation of continents, or extensive tracts of country, was (as Mr. Lyell maintains) a long continued process. It may be proved that these operations were distinct from each other, as I shall afterwards state.

direction, and frequently took the arched form of stratification, as represented Plate II, fig. 2, *x*, *y*.

Indeed, M. Elie de Beaumont has himself been obliged to modify his generalizations considerably, as will appear from the following extract from the *Bulletin de la Société Géologique de France.* M. Reboul, in a memoir on the structure of the Pyrenees, read to the society in December, 1831, states, that several distinct axes of elevation may be observed in different parts of these extensive mountain ranges, inclined in different directions to each other, and that the lines of bearing of the strata, are also different in each. There are, he observes, indications in the Pyrenees, of the elevation of rocks at different epochs, both before and after the most recent secondary depositions, that rise to the summit of Mont Perdu. He also states instances of the tertiary beds of molasse, being elevated near the central range of the Pyrenees, whereas in the Alps, they only occupy the central parts of the range, which would imply that the period of elevation of that part of the Pyrenees, was more recent than that of the Alps. It appears, however, in the same report, that M. Elie de Beaumont now admits four epochs of elevation in the Pyrenees: the most ancient immediately succeeded the formation of the transition rocks. The second took place between the deposition of the green sand, and that of the upper chalk. The third epoch of elevation was posterior to the chalk formation. The fourth, which gave birth to the serpentines (*ophites*,) and to the gypsum with rock salt, is more recent than the tertiary epoch.*

M. Beaumont, however, contends, that notwithstanding the four different directions of the ranges in the Pyrenees, of which traces may be observed in several of the valleys, the great chain of the Pyrenees, owes its actual elevation and general direction to the third system or epoch of elevation, which was posterior to the chalk formation; the two former epochs of elevation, discoverable in this chain, having been modified by the great elevation of this third epoch. The fourth epoch of elevation is only perceivable in the localities where serpentine rocks appear.

I wish to press upon the attention of geologists the consideration, that the arched stratification implies a very limited extent of operation. Where it is confined to one mountain, as at Crich Cliff, (see the cut, p. 105,) the elevating force may be said to act at one point. Where the arched stratification extends through a range, it may be said to act along narrow lines, forming moun-

* The formation of serpentine (which was formerly considered as a primary rock,) after the tertiary epoch, will cease to surprise geologists, since the identity of basalt, green stone, and serpentine, has been ascertained by Dr. MacCulloch. Serpentine, like basalt and volcanic rocks, may have been formed among any class of rocks. It was stated in Chapter XII, that some of the rock salt deposits in Poland were in tertiary strata.

tain ridges, with valleys between them. From what I observed in the Alps, I was convinced, that the explosive force which upheaved Mont Blanc, and the central range of the Alps, did not extend its action very far from the axis of the range on each side; and that this action, being confined within narrow limits, produced a rent or line of fracture on the crust of the globe, along which the beds were suddenly tilted into their present position; and that the outer ranges were raised by similar explosions, acting along lines of fracture of greater or less extent. These upheavings, whether simultaneous or successive, took place under the sea, and must have occasioned an agitation of the water, far exceeding in violence any thing which modern causes present to our observation.

The vertical, or highly elevated position of strata, that were originally horizontal, implies the sudden and violent action of an upheaving force. In elevated mountain ranges, where the strata are not highly inclined, we may infer, that the upheaving force was slow in its operation, or acted on a large segment of the earth's surface.

I now claim the attention of geologists to the following position, which admits of direct and positive proof, though I am not aware that it has been before noticed. The emergence of large islands and continents from the ocean, was not effected by the same operation as that which tilted up the beds of primary rocks in many mountain ranges. The lower or primary rocks, after they were tilted up, were still beneath the level of the ocean, when they were covered by the secondary strata unconformably, as many of these strata are marine formations. It is possible, that in some ranges the summits of the ancient rocks might, after they were tilted up, rise above the level of the sea, and form islands; but the land, as we now observe it, must have been beneath the sea.

The section of the Charnwood range, Plate II, is not taken through the highest part. Beacon Hill and Bardon Hill are at least five hundred feet higher than the surface of the red sandstone *a a*, and it is probable that they were once much higher than at present, and their summits may have risen above the sea which deposited the strata of red sandstone on the lower parts of the range.

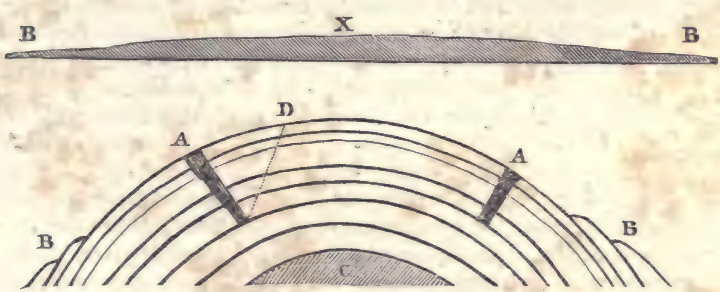
Should any one suggest a doubt, whether this portion of the new red sandstone was deposited under the sea, it is only necessary to say, that the same new red sandstone immediately adjacent to the Charnwood range, is covered by beds of the lias formation, (see *e* in the same plate,) which abound in marine organic remains. The same reasoning will apply to all other situations in which uptilted transition or primary rocks, are covered by horizontal depositions of secondary strata. The elevation of the

uptilted beds was a distinct operation from that which raised them, together with the rocks that cover them, above the ocean, and which converted the former bed of the sea into dry land.

I consider it probable that all large tracts of country or continents, emerged slowly from the ocean, forming at first mountainous islands, before the lower countries were raised above the level of the sea. The power which could upheave a continent, or, in other words, occasion a large portion of the crust of the globe to swell out, must be very different from the force which acted along certain lines, and elevated mountain ranges. This power may be dependent on a more general law of subterranean motion, with which we are at present unacquainted. We might offer many instances in our own island, in which the forces that have broken and lifted up the strata along certain lines, evidently appear to differ from the force which elevated continents or large islands. The elevating force that broke and tilted up the chalk strata, along a line extending east and west through the Isle of Wight into Dorsetshire, does not appear to have produced any considerable change at a distance from the line or axis of elevation.

In passing from Alum Bay, where the chalk strata are nearly vertical, to the south side of the island, it is truly extraordinary to observe, how little the lower beds beneath the chalk, and adjacent to it, appear to have been disturbed. The force which uptilted the strata is altogether distinct from that mighty upheaving force, which raised the whole chalk hills in the south of England from the ocean, without disturbing the relative position of the strata.

The annexed cut from page 155, may farther illustrate the elevation of mountain ranges.



The lower fig. B A B, represents the transverse section of a narrow mountain ridge, elevated by some upheaving force situated below C. The highest part of the ridge is the line or axis of elevation, called the anticlinal line, from which the strata on each side dip in an opposite direction. In this section the strata are

not broken, but arched or *saddle-shaped.* If the upheaving force be concentrated along a narrow space, the upheaving may extend for many miles in length without disturbing the beds situated at a little distance from the anticlinal axis. The upper fig. B X B, may represent the transverse section of a range twenty miles in breadth and 1500 feet in height, like the central range that separates the Yorkshire and Lancashire coal fields. In this section, unless there are several parallel lines or axes of elevation, we must suppose that the upheaving force was seated lower and acted with less intensity in a given time, than the force which elevated the range B A B. In excavating a tunnel for the Huddersfield canal about four miles in length, which passes through the mountain called Pule Moss, near the center of the range, the axis of elevation at X was cut through, from which the strata dipped in opposite directions. The strata are chiefly millstone grit, but the axis was a fissure filled with large flattened spheroidal balls of impure ferruginous limestone.*

It must be obvious, that the broadest mountain ranges, must either have several parallel axes of elevation, or that the upheaving force must be situated deep under the surface. Elevatory powers may either be limited like those which have upraised the strata in coal fields, or they may be very extensive in length, like those which have elevated the Alps. Where the length and breadth are both extensive, they may form large islands, or large portions of continents. It is, however, certain that the surface of the globe has, in many parts, been several times elevated above the ocean, and again submerged under its waves for long periods. The coal strata offer decisive proofs of such changes. See Chap. IX. The Portland strata and the Wealden beds present evidence of submergence and elevation, which are equally satisfactory. Chap. XIV. Instances of elevation from the ocean are offered by all calcareous mountains containing marine organic remains. Instances of depression are more rare. The following account, if verified, is extremely interesting. M. Humboldt in a recent work, entitled *Fragmens Géologiques sur l' Asie Centrale*, the result of his late travels into Asia, observes, that the high part of central Asia, commonly called *le grand plateau*, is composed of four powerful ranges (*systèmes*) of mountains, directed east and west, and supported by a common base, also raised above the surrounding country. At the foot of this immense system of mountain chains and elevated ground, is an enormous depression of eighteen thousand square leagues, and from 150 feet to 300 feet below the level of the ocean. The surface of the Caspian Sea and the level of Astracan is 300 feet lower than the sea, and the

---

* See further remarks on the elevation of this central range, p. 153 to 157, Chapter IX.

course of the Volga is 150 feet lower. M. Humboldt supposes, that this subsidence was the result of the elevation of the Plateau, which supports the Himalaya and Irun mountains, and perhaps those of Caucasus, an enormous mass, the elevation of which can be compared to no geological phenomena, of the same order, observed on the other continents.*

The most remarkable elevation of the ground that has been noticed in modern times, is that which took place on the coast of Chili near Valparaiso in the year 1822, when the bed of the sea was raised permanently above the surface, over an extent of 100 miles in length: see page 73.

Mrs. Graham, who was at Valparaiso during the numerous earthquakes that succeeded each other from Nov. 19th to Dec. 25th, describes very clearly the attendant phenomena. The granite on the beach is intersected by parallel veins, filled with crystalline matter. After the earthquake of the 19th, the whole rock was found rent by sharp recent clefts, very distinguishable from the older ones, but running in the same direction. Mrs. G. says, that when the general tremor was felt, a sound of rushing vapor was heard, like that which is often heard on Vesuvius, during an eruption. Cones of earth, about four feet high, covered the whole plain of Vina-a-la-Mar. These cones were formed by water and sand, forced up through funnel-shaped hollows beneath them. These appearances indicate the intense action of pent-up vapor. The coast near Valparaiso was raised from three to four feet. Mrs. G. further states, "*I found good reason to believe, that the coast had been raised by earthquakes in a similar manner at former periods, several ancient lines of beach, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea.*"

The earthquakes on the coast of Chili in Feb. 1835, appear to have been more terrific than those of 1822, and to have raised the coasts of some of the neighboring islands from six to nine feet.—See Chap. XIX. pp. 308, 309.

The elevations of limited portions of the earth's surface, at a distance from any known volcanic agency, are not uncommon. Loose stones or shingles of an ancient sea beach, are found at heights considerably above the present level of the sea, in many parts of England.

---

* Considerable doubts have been expressed respecting the accuracy of the barometrical measurements, by which the level of the Caspian Sea was determined to be 300 feet below that of the Black Sea, in 1830: the government of Russia, at the desire of the academy of sciences at Petersburgh, have now appointed three able mathematicians, provided with suitable levels, and other instruments, to ascertain the precise difference of elevation between the two seas. The result of their labors may soon be expected to be published, which will determine with certainty this important inquiry.—See *Journal of the Royal Geographical Society*, 1836, Vol. VI, Part II.

On the coast of Norway and Sweden, Von Buch and M. Brongniart discovered deposits of shells at various heights above the level of the sea; this would indicate that the rocks have been elevated at a recent period, though they are chiefly composed of gneiss and primary formations. Adjacent to volcanic districts, instances of the repeated elevation and submersion of the land are not uncommon. In the first volume of Mr. Lyell's Principles of Geology, many interesting facts of this kind, in Calabria and Sicily, are fully stated.

In the address of Mr. Lyell to the Geological Society of London, 1837, he has stated several instances of the gradual elevation of the shores of the Baltic in some parts, and of subsidence in other parts, attested by satisfactory evidence. In some of these cases the elevation or submergence has not exceeded a few inches in a century. In other instances, the subsidence has been more rapid, for there are towns along the coast of Scania, where the streets are below the level of the sea. On the coast of Greenland, a great change in the level of the ground has taken place, since the period when a colony of Europeans was settled there. Several of the coral islands in the southern Pacific offer incontestable proofs of recent elevation, for the uppermost beds of coral, rise considerably above the level of the ocean, where no coralline polypi could have lived.

Although we have few recent instances of subsidence of the land on an extensive scale, cities have been ingulfed and their place occupied by lakes, and the bed of the sea near the coast, has been deepened as well as elevated by earthquakes. In addition to this, there are submarine forests on some parts of the English coast, particularly of Yorkshire and Lincolnshire, which may be seen, at low water, extending far into the sea. The trees are broken off near the roots, but their stumps are erect, proving that they are in the position in which they grew; this fact clearly indicates a submersion of that part of the country at no very remote epoch. If ancient traditions could be relied upon with as much certainty, as the records of nature imprinted on the crust of the globe, we might cite the fact of ancient continents having sunk down, since the world was peopled by the human race. Plato, in his dialogue entitled *Timæus*, says, that Solon received an account from the priests of Sais in Egypt, that there was formerly a vast country called the Atlantides, situated beyond the Straits of Gibraltar, the inhabitants of which were highly civilized and flourishing; but the whole country was ingulfed in the ocean, during a violent earthquake.

The upheaving of extensive islands or continents, was probably always accompanied by the depression of other portions of the crust of the globe: the oscillations of the surface may be the result of some general laws of subterranean motion, as regular

and definite in their operation, as the laws which regulate the motions of the planetary system. These laws may for ever remain undiscovered by human intelligence, but our ignorance respecting the causes which have repeatedly submerged and elevated various portions of the earth's surface, does not invalidate the fact, that such submersions and elevations have taken place at various epochs. The admission of this fact has been progressively gaining ground, and is supported by a mass of evidence that cannot be refuted.

CHAPTER XXIV.

ON THE FORMATION OF VALLEYS, AND THE GEOLOGICAL THEORIES RELATING TO VALLEYS AND DENUDATIONS.

On the Causes that have broken the Surface of the Globe.—Erosive action of running Water illustrated by the Process called *Hushing*.—Bursting of Lakes.—Some Valleys originally formed by Elevation or Subsidence, and subsequently enlarged by the Action of Water.—Different Theories respecting the Formation of Valleys.—Theory of Werner—of Hutton.—Of Elevation.—Of the retiring Waters of the Ocean.—Theory of Excavation and Denudation by Deluges.—Modification of this Theory by Sir James Hall; its Application to explain Denudations, and Transportation of Blocks of Granite from the Alps.—Particular Phenomena presented by the scattered Blocks in the Vicinity of Geneva.—Denudation of Stratified Rocks, effected by the same Causes which have broken the Primary Rocks, and scattered their Fragments into distant Districts.

From what has been stated in the preceding chapter, respecting the elevation and submersion of the earth's surface, the geological student might infer, that such elevations and submergences offer a sufficient explanation of the formation of valleys, but the inference would be erroneous. The causes which have modified the surface of the globe are either internal, viz. dependent on the earth itself, or external, dependent on the atmosphere which surrounds it. Beside these, there is the ceaseless flux and reflux of the ocean, dependent on the attractive forces of the sun and moon, and on the earth's diurnal revolution on its axis. The two former causes have been principally concerned in the formation of valleys; and there are few valleys, in which the combined effects of both these causes may not be traced. The inequalities of surface produced by the upheaving of mountain ranges, or the emergence of continents from the ocean, must have originally determined the course of the retiring water, or of atmospheric water precipitated in rain.

Of the power of atmospheric water to act upon the surface of the globe, we can form but a very feeble idea from what we observe in our own country. In warm climates, as much rain will fall sometimes in one hour, as falls at different times during three months in northern latitudes: added to this, when the rain descends in mountainous regions, the water is suddenly collected into powerful rivers, rushing with incredible violence to the lower valleys. At remote epochs, it is highly probable, that many elevated depressions, which are now mountain valleys in Alpine regions, upheld the waters and formed lakes, that have subsequently burst their barriers, and have ploughed a passage for the succeeding rivers, when the drainage of the country became more regular.

At the present day, the bursting of mountain lakes is not unfrequent in the Alps. When the streams that run through elevated Alpine valleys are dammed in by a barrier of ice, or by a fall of stones and earth from the overhanging rocks, mountain lakes are formed, which produce overwhelming torrents, whenever the barriers are by any cause removed.

To convey to the reader some idea of the force of falling water, carrying with it loose stones that occur in its passage, it may be useful to describe a process called *hushing*, in Westmoreland. The quarrymen, when in search for good beds of slate, where the side of a mountain is covered with stones and vegetation, form a lake or pool near the top of the mountain, by damming up a mountain rivulet where it passes through a depression or small valley. When the water has accumulated in sufficient quantity, they dig a trench near the dam, to direct the current where they wish it to flow, and then break down part of the dam. The water flows first through the trench, and rushing with accelerated velocity down the mountain, carries with it the stones near the surface, and in a very short time ploughs a deep channel in the rocks, exposing every bed to view. Thus, in a few hours, is effected what the labor of many men, continued for months, could not have accomplished. I have been informed, that in the upper part of the valley of Long Sleddale, when the process of *hushing* takes place, the river Ken, (as it flows by Kendal, twelve miles distant,) is made turbid for some days, by the quantity of débris carried into it. If such an effect can be produced by the small quantity of water thus pent up, it will not be difficult to believe, that the bursting of extensive mountain lakes may have scooped out passages for mighty rivers. Even the bursting of a small mountain lake, in the valley of Bagnes, in the year 1818, produced the most terrific effects. The lake had been formed by a barrier of ice damming up the river at a great elevation: this barrier suddenly gave way, and precipitated the water into the great valley of the Rhone, near Martigny, tearing down and overturning every obstacle it met in its passage. From the quantity of mud and stones which it bore along, it resembled a moving mass of stones and earth. An English gentleman, who was descending the valley at the time, observed his horse exhibit by its motions great trepidation, of which he could not discover the cause, until a loud rushing noise occasioned him to look back, when he beheld what appeared like a wall filling up the bottom of the valley, and advancing rapidly towards him. He instantly alighted, and scrambled up the adjacent rocks, leaving his horse to its fate. Two years afterwards, when I was at Martigny, the desolating ravages of this catastrophe were apparent. This place has experienced many similar catastrophes from the same cause.

Many of the lower valleys in the Alps have evidently once been lakes. The whole valley of the Rhone, from its source to Martigny, formed one lake: the broad valley of Geneva, between the Alps and the Jura, formed a lower and more extensive lake, before a passage was opened for the water at Porte l'Ecluse. When a fissure was once made by earthquakes or by subsidence, the rushing of water charged with stones, would enlarge and deepen the passage, and thus lay dry and reduce the ancient lakes in a comparatively short period. In the year 1819, part of a mountain immediately above the river Isère, opposite to the city of Moutiers, in the Tarentaise, suddenly fell down into the river, and formed a dam across it, over which persons might pass from one side to the other. When I was there in the year 1821, all this mass of stone had been carried away by the river. The action of rivers, in extensive and level valleys, tends rather to fill them with débris, brought from the more elevated countries in which the rivers had their origin, than to excavate them deeper.

The formation of the greater number of valleys cannot be explained by the action of water alone. There are valleys of elevation formed by the raising of the strata on each side—valleys of subsidence, formed by the sinking of the ground, leaving the adjacent rocks unmoved—valleys of disruption, where a range of mountains, or an extent of country, has been rent by earthquakes or by subsidence. Most of the valleys formed originally by these causes, have been subsequently enlarged or modified by the action of water. There are, indeed, instances of valleys and ravines, formed entirely by the continued erosion of water; such is the valley of Niagara, between Queenstown and the Falls. (See the frontispiece to the present volume.) Other instances might be cited, in which the action of water is equally evident. In many cases, however, where water appears to have been the sole agent in excavating rocks, I am inclined to believe, that an original break or fissure has greatly accelerated the process. In broad valleys, the excavation must often have been effected by more powerful agents than any which we perceive in present operation, and when a broad outlet is once made, the subsequent drainage of a country may work its way to the sea in a very sinuous course; but this sinuous course does not prove that the valley had been originally formed by the river that flows through it.

Besides the action of mountain torrents, the bursting of lakes, and the regular flowing of rivers, many geologists believe that the excavation of valleys, and the transportation of loose rocks, have been effected by the more powerful agency of the ocean, thrown over the surface of the land, by the great convulsions that have upheaved mountain ranges and continents. For the benefit of the geological student, I shall endeavor to give a brief outline of the principal theories that have been maintained respecting the

formation of valleys, but the first of these theories is now admitted to be untenable.

The formation of valleys has been ascribed to the following causes:

1st, To the original unequal deposition of the earth's surface.

2d, To excavation, by the rivers that flow through them.

3d, To the elevation or subsidence of part of the earth's surface.

4th, To excavations, caused by the sudden retreat of the sea from our present continents.

5th, To excavations, by inundations or deluges, that have suddenly swept over the surface of different parts of the globe.

I shall notice the leading facts that favor or oppose each of these theories.

The first of the above theories is that of Werner: he supposed that all the matter of which primary, transition and secondary rocks are formed, was originally held in solution by water, and that the water, so saturated with mineral matter, covered the whole globe. The primary rocks of granite were formed by chemical precipitation, and their peaked summits and declivities were the result of their original deposition. On the steep sides of these primary mountains were subsequently deposited the different schistose rocks, and the secondary strata were formed over these by the mechanical breaking down of the primary and transition rocks. During the time that these rocks were depositing, the water, though nearly saturated with mineral matter, was capable of supporting animal life, and the shells and remains of zoophytes and fish, were enveloped in the strata at the period of their deposition. According to this theory, when the water retired from the present continents, the mountains and valleys were already formed.

The theory of Werner requires for its support the admission of conditions, which appear in the present state of our experience impossible, and it is at variance with existing phenomena. The vertical position of beds of puddingstone, sandstone, and the tertiary strata, in the Alps, could not have been their original one; nor can the bendings and contortions of the strata, so common in Alpine countries, be explained by original deposition. A further account of part of Werner's theory is given, Chap. X.

The second theory, that all valleys have been excavated by the rivers that flow through them, was maintained by Dr. Hutton and Professor Playfair: it formed a part of their general theory of the earth; the leading propositions of which are, that the surface of the present continents is wearing down by the action of the atmosphere and by torrents, and that the materials are carried by rivers into the sea, and there deposited. At a future period these materials will be melted or consolidated by subterranean heat

under the pressure of the ocean, and subsequently, by the expansive force of central fire, the bed of the ocean will be elevated, and form new continents. According to this theory, our present continents have been also formed from the ruins of a preceding world, and elevated by a similar cause. It is only with that part of the Huttonian system, which relates to the excavation of valleys, that we have at present any concern.

It is remarkable, that a theory which maintains that the continents were raised from the ocean by subterranean fire, should limit the formation of valleys to the action of the rivers that run through them; for if the land were raised by an expansive power acting from beneath, it seems to follow as a necessary corollary, that the surface would be unequally elevated and broken by the same cause; unless we suppose, that every part presented an equal degree of resistance to the moving force. If the resistance were unequal, there must have been original inequalities or valleys, which determined the direction of the water courses in the first instance, though the form of these valleys may have been subsequently modified by the action of water. That all valleys have been excavated by the rivers that flow through them, is opposed by many decisive facts. Before their excavation, the surface would be nearly level and the water must have had less force than at present, as the fall would be gentle. The present effect of rivers in large valleys, is not to excavate them deeper, but to fill them with alluvial depositions.

There are numerous deep valleys in the Alps, that are closed at one end by steep mountains or perpendicular walls of rock, and are now nearly closed at the other end. Such are the valley of Thones, near Annecy, the valley of Chamouni, and on a larger scale, the valley of Geneva. It is evident that the valley of Thones, and that of Geneva, have once been filled with water, and formed lakes: by an earthquake, or by the erosion of water, a fissure has been made, which has drained the greater part of these valleys; but it is obvious that the valleys could not have been formed by the original lakes, or by the rivers that flowed into them. If valleys were formed by the erosion of rivers, the lakes through which these rivers flow, must have long since been filled up by the materials brought into them. To say that the lakes were once deeper than at present, is giving up the theory, for lakes are only the deeper parts of valleys.

Had the valley of Borrowdale, in Cumberland, been excavated by the water that flows from it, the lake of Keswick, at its entrance, must have received all the materials, and been long since choked up. Or had the valley of the Rhone, ten thousand feet deep and sixty miles in length, been excavated by the Rhone, the quantity of matter brought down by this river, would not only have filled the lake of Geneva, into which it empties

itself, but the broad valley in which the lake lies, must also have been filled up, and raised to the height of the Jura. That the Lake of Geneva, and all lakes into which large rivers flow, are gradually filling up, has been before stated; but the valley of the Rhone is not, nor are other valleys becoming deeper.

The action of torrents in Alpine districts may have been sufficient to widen fissures already made, or to scoop out glens, in the softer beds on the sides of mountains; but they appear inadequate to the original formation of large longitudinal valleys. Water courses running on the edges of nearly vertical beds, may scoop out a portion of a softer bed, placed between two hard rocks, and thus form small longitudinal valleys. I have observed several instances of such valleys in the Alps, which may probably have been furrowed by mountain torrents in the course of ages. Some valleys, as Les Echelles, near Chambery, are closed at one end by a perpendicular wall of rock; through this rock a tunnel has been cut for the road: but it is impossible to conceive, that any action of water courses could have formed such a valley. There is only a feeble stream that flows from it.* Malham Cove, at the head of the valley of the Aire, in Yorkshire, is a perpendicular wall of limestone 200 feet high: at its feet the river rises; but no conceivable action of the river could have originally formed this valley. Whatever extension we may reasonably grant to the action of rivers, it will not be found sufficient for the excavation of valleys, except in particular situations.

The third theory, which attributes the formation of valleys to the elevation of mountain ranges, appears to assign a cause, that will explain, in a simple manner, the formation of many valleys; but on examination, it will be found inadequate to explain the phenomena of other valleys, without the concurrence of inundations or the action of water.

If the crust of the globe were broken, and raised in parallel ridges, such ridges might form mountain ranges, with valleys between them, like what are observed bordering the central range of the Alps; the arched stratification of many of the calcareous mountains, and the vertical position of the beds favor this hypothesis.

In some instances, where the beds of a mountain are raised from an horizontal to a nearly vertical position, they would leave a chasm proportionate to the part that had been raised; and this might form the bed of a lake. The steep escarpments, which the calcareous mountains in Switzerland and Savoy present on one side of the lakes which they border, indicate that the beds of the lakes were formed in the hollows that had been left by

---

* For a particular account of the structure of this valley, see Travels in the Tarentaise, vol. i, p. 169. I there ascribe its original formation to subsidence.

the elevation of the mountains. The beds of the mountains on the side opposite to the escarpments, generally slope down to the lakes: hence M. De Luc inferred, that it was these mountains that had sunk down, and left the chasm which forms the bed of the lake. Indeed it is highly probable, that when the beds of rock were broken and elevated in one part, the beds adjoining would sink down, leaving vast chasms, which were soon filled with water, and formed lakes. It seems quite certain, that the lakes in the valleys of mountainous countries, could never have been excavated by the rivers that flow into them. The great lakes of North America are situated upon a vast extent of table land, about 800 feet above the sea; but the country is so level, that the rivers which flow into the lakes, and those which empty themselves in the gulf of Mexico, are only separated at their sources by elevations not exceeding a few feet, and when swelled by rain, the northern and southern rivers sometimes interlock. In this plain there are no mountains. These lakes were probably formed by partial subsidences, at the epoch when the whole country was upheaved from the ocean.

Transversal valleys, or those which cut through mountain ranges, nearly at right angles to the direction of the ranges they intersect, may have been originally fissures or openings, made either at the period when the ranges were elevated, or subsequently, by the same causes that have rent and displaced the secondary strata. These fissures may have been afterwards widened by the erosion of water.

Geologists seem now generally agreed, that the action of rivers is not sufficient to explain all the phenomena of valleys, and still less to account for the fragments of rocks scattered over extensive plains, at an immense distance from Alpine districts, where rocks similar to these fragments occur. Another phenomenon, of more importance, is altogether inexplicable by the action of rivers. Immense tracts of the secondary strata, several hundred feet in depth, have in some districts been torn off, and the materials entirely removed, except detached patches, which here and there form isolated caps on distant hills; and incontestably prove, that they were once parts of one continuous stratum or formation. Numerous instances of this might be cited in our own island. It is probable that the beds of chalk that form the north and south downs of Sussex, once extended over the Wealden beds. See p. 10. This local disappearance of a stratum or formation, has properly been called a *Denudation*.—See denudation of the chalk described, p. 247, 248. If what was stated in Chap. IX. respecting the original soft condition of the strata be admitted, it will diminish the difficulty attending the explanation of denudations. That the agent by which the strata were removed was water, is now generally believed, but whether the denudation took place

before the strata emerged from the ocean or subsequently is uncertain.

The fourth theory, which attributes the formation of valleys to the sudden retreat of the sea from our present continents, is founded on the admitted fact, that the sea has once covered them; and whether we suppose that the bed of the ocean was deepened in one part by a sudden subsidence, which drew off the water from another part, or that the continents emerged, by an expansive force acting beneath them,—the effect on the water would be nearly the same. This effect, in scooping out valleys, has been compared to what may be observed in miniature "by the drainage of the retiring tides on muddy shores, especially in confined estuaries, where the fall is considerable and rapid," the water cutting out channels for its passage, as it drains off. The retiring of the ocean suddenly from the present continents, would be a cause sufficient for the excavation of valleys; but I have stated, in the preceding Chapter, the reasons for believing, that continents emerged from the ocean, by the long continued action of an upheaving or expanding force.

The fifth theory, which ascribes the formation of valleys, and the extensive denudations of the strata, to deluges that have suddenly swept over different parts of the globe, has been maintained by Professor Pallas and Sir James Hall. The former conjectured, that the inundations that have covered parts of the Asiatic continent with blocks of stone, beds of gravel, and marine remains, were occasioned by the formation of volcanic islands in the Indian ocean. Within the period of authentic history, extensive inundations have been occasioned by volcanoes and earthquakes, which afford probability to the opinion of Pallas. In the year 1650, a new volcanic island rose from the sea in the Grecian Archipelago; and according to the account of Kircher, a contemporary writer, it occasioned the sea to rise forty five feet in height, at the distance of eighty miles, and destroyed the galleys of the Grand Seignior in the port of Candia. The principal damage done by earthquakes to cities adjoining the sea, is often effected by an enormous wave: the sea, retiring from its bed in the first instance, suddenly returns with a prodigious swell, and in a few moments rushes over the adjacent country.

During the earthquake in Chili in 1835, see p. 308, 309, a permanent elevation of the ground of about nine feet took place, and the sea rose to the height of from thirty to forty feet, sweeping over a great extent of land, and tearing away the various obstacles opposed to its progress. If we suppose mountains several thousand feet high were elevated by similar causes, the swell of the sea must have been inconceivably overwhelming.

Sir James Hall has given greater extension and consistency to this speculation. He supposes that the upheaving of a large island

like Sumatra, might take place so suddenly as to drive the ocean with great impetuosity over the summits of the highest mountains and strip off the glaciers, and transport them into distant countries. Ice being specifically lighter than water, the glaciers would carry away with them the blocks of stone that had fallen from the impending rocks, and had become incased in ice. This theory of Sir James Hall's would, I conceive, offer a better explanation than any other, for the occurrence of groups of fragments of particular rocks, unmixed with fragments of other rocks. Each glacier, loaded with stones from the rocks above it, may be regarded as a ship freighted with specimens of its native mountains, which it deposits, by thawing, in the place where it ultimately rests. Nor would a wave or swell of the sea, that had covered the highest mountains, suddenly subside; it would sweep repeatedly over the whole surface of the globe, at a lower and lower level each time, breaking down opposing obstacles, opening new passages for the water, and scooping out valleys and cols in the softer beds and strata.*

Of the different theories relating to the formation of valleys, that of Sir James Hall appears to offer the most satisfactory explanation of the transporting cause, by which scattered blocks of rock have been removed from their parent mountains into distant countries, and sometimes spread on the summits and sides of mountains, separated from each other by deep and broad valleys. These scattered blocks, as well as beds of rounded stones, have been referred to in the Chapter on Diluvial Beds. Their occurrence presents great difficulties to the contemplation of the geologist, which few of the theories of the formation of valleys will assist in removing. Without travelling to the Alps, we meet with difficulties of this kind in the midland counties of England. For instance, there are beds of gravel, and fragments of rock, scattered over hills, that are not only far distant from the rocks which have supplied the fragments, but which are separated from them by deep valleys, over which it is supposed that the fragments could not have been carried, by any power of diluvial agency; for in England we have not the glaciers to assist in their transportation. It has been imagined, that these fragments and beds of gravel, were deposited in their present positions, before the intervening valleys were scooped out. But any subse-

* Those depressions in a range of mountains which offer the easiest access in crossing from one valley to another, are in the Alps called *Cols*. I observed that these cols were all in the softest beds; and their formation admits of an easy explanation by diluvial action. See Plate II, fig. 2. "A range of mountains, with their beds highly elevated, is extended from *a* to *d d*. At *c c* the beds are of very soft slate or shale, which has been excavated so as to offer a passage over the range, though the highest part is several thousand feet above the valley. Such is the Col de Balm above Chamouni. The beds probably extended, at the period of their elevation, in the direction of the dotted lines."

quent deluge, sufficiently powerful to scoop out valleys, must have swept away the loose stones on the surface. The local elevation of the surface would in these cases appear to offer a more satisfactory explanation. The blocks of granite torn from Mont Blanc and the adjacent granitic range, are scattered over the calcareous mountains, and in the valleys of Savoy, to the distance of sixty miles or more from the parent rocks, and some of these blocks have traversed the Jura into France, a distance of 100 miles. Two hypotheses have recently been formed respecting them: the one, that these blocks of granite were thrown from the mountains by an expulsive force at the period of their elevation; the other, that the calcareous mountains have been subsequently raised, with their load of granitic blocks upon them.

The first of these theories, will not be regarded as entitled to farther observation. The second is opposed by certain appearances in the Alps, which indicate that the mountains were raised, before the scattered blocks were deposited upon them, but it is not improbable, that the same mountains may have received additional elevation, subsequently to the transportation of the blocks that rest upon them. The range of the Jura, over which some of these blocks have passed from Mont Blanc, might not at that time have attained their present elevation. The transportation of erratic blocks, cannot be properly investigated, without taking into consideration the valleys and hills, which appear to oppose their progress. The facts connected with this inquiry are nowhere more distinctly seen than in the vicinity of Geneva. If any readers of this volume should visit that city, I would recommend them to devote a day to visiting the mountains called the Great and Little Saleve, in its immediate vicinity. They present their steep escarpments of limestone to the valley of the Rhone, but slope down on the south side to the valley of the Arve. On this southern side may be seen, not the remains of an ancient temple or city, but the magnificent ruins of mighty mountains, and the monuments of an overwhelming catastrophe, which transported these ruins into their present situation. The snow-clad mountains from which they were torn, rise magnificently to the view, though fifty miles distant. On the Little Saleve, at the height of fourteen hundred feet above the valley, are scattered numerous blocks of granite of vast size, not at all water-worn, and almost as fresh as if recently torn from their parent mountains; they are of that kind of granite called Protogine, in which talc or chlorite is one of the component parts, and are identical with the granite of Mont Blanc, while the Saleve on which they lie and the surrounding mountains are calcareous. On the Great Saleve adjoining, there is one block of this granite seven feet in length, at the height of 2500 feet above the valley. Saussure has remarked, that these blocks are not broken or shattered, as they would have been, had they been hurled with violence from the Alps; neither

do the limestone strata beneath them present any appearance of having been fractured or indented by their fall: on the contrary the blocks lie upon the surface. Two of these blocks of granite rest upon pedestals of limestone, a few feet above the general level of the ground. The blocks have evidently protected the limestone beneath them from disintegration, and thus would serve as chronometers, to indicate the period when they were deposited, could we ascertain the thickness of surface worn away in a given time.

I observed a few of the blocks were cracked, but this was in all probability effected by the percolation of water, and its expansion by frost. Another circumstance pointed out by Saussure is, that these blocks, in their passage from the Alps, appear to have taken the course of the present valleys, and where they have been carried as far as the Jura chain, they rest at various heights on the sides of that range of mountains, exactly opposite to the mouths of the Alpine valleys. Saussure, however, supposes, and with much probability, that the whole of the valley of Geneva, and the valleys that run from the Alps, and all the lower mountains of Savoy, were covered by the sea at the period when the great catastrophe took place, and that the rocks were torn off and transported by a sudden rush of waters. He further supposes, that the specific gravity of the blocks being diminished by the medium in which they were borne along, they might be carried to a great distance by the violence of the current, and deposited at considerable altitudes. That these valleys were formed before the transportation of the granite blocks, seems evident from the circumstance before stated, that the blocks occur in groups, opposite to the embouchures of all the Alpine valleys, that open into the great valley of Geneva. These valleys or depressions, were therefore formed before the country emerged from the ocean, not by the erosion of rivers, but by the elevation and fracture of the beds on each side. The summits of the mountains that border the present valleys, may have directed the course of the rush of water by which the blocks were transported. The valley of the Arve, in the upper part, has evidently been a lake, or series of lakes, originally formed by elevation and depression: the waters have cut passages through the barriers of these lakes at a subsequent period, and the river Arve has afterwards cut through the deep mass of sand and rounded stones, that fill the bottom of the lower part of the valley, from Bonneville to the junction of the Arve with the Rhine. The transportation of the granite blocks was posterior not only to the original formation of the Alpine valleys, but also took place at a later period than the deposition of the deep mass of sand and rolled stones, that forms the bed of the lower part of these valleys, for the blocks often rest upon it. Blocks of similar granite may be seen in the lake of Geneva. between that city and Thonon, which indicates that this part of

the lake has undergone no great change, since these blocks were deposited. The transportation of the granite blocks appears to have been effected suddenly; but the rounded blocks and sand at the bottom of the valleys, must have been long subjected to the violent agitation of water.

There are numerous instances of transported masses of rock scattered over our own island, and various parts of the continent, but none of them appear so immediately to elucidate the inquiry respecting the origin of valleys, as the granite blocks in Savoy, and on the Jura. Seated on the side of a mountain, among a group of these blocks (as on the Saleve, near Geneva;) you may see, at the same time, the distant rocks from which they were torn, the valleys or depressions along which they have been transported, and the original situations on which they were deposited, and where they remain, and may probably continue till another great revolution of the globe.

In the preceding account of the transportation of the blocks of granite from Mont Blanc and its vicinity, it is stated, that their course was in the direction of the valleys that open into the great valley of Geneva. It would be more correct to say, their course was determined by the depressions that now form valleys, but were then filled with water, nearly to the summits of the rocks, which border the valleys on each side. Assuredly the scattered masses of rock could not travel along the bottom of the present valleys, and cross the lake of Geneva, and then ascend to a great height on the side of the Jura.

No theory that I know of can offer a satisfactory explanation of the blocks of peculiar rocks from certain mountains, being unmixed with any other, and deposited together, unless we admit, that they were brought by floating glaciers, freighted with the fragments of the rocks above them. The blocks of Saussurite, described at page 85, as occurring in a field near Nyon, on the lake of Geneva, are 120 miles distant from the nearest similar rock, which is in the valley of Sass, that opens into the upper valley of the Rhone at Visp.

Let any one acquainted with the Alps, look at the admirable "*Carte Militaire des Alpes*," by Raymond, which is a correct bird's-eye view of this wonderful region, and say whether it appears possible, that the blocks of Saussurite could have travelled so far, unmixed with other rocks, except they had been transported from their native situation by a floating glacier.

Where transported blocks and stones occur in any country, intermixed with the bones of extinct species of terrestrial animals, we cannot deny, that the inundation or current, by which they were removed, has swept over the surface of an island or continent. Such transported blocks and beds of stone, are in the strictest sense of the term diluvial.

54

CHAPTER XXV.

ON THE ANCIENT TEMPERATURE OF THE EARTH.—ON CENTRAL HEAT, AND ON ASTRONOMICAL PHENOMENA ILLUSTRATIVE OF GEOLOGICAL THEORIES.—CONCLUSION.

It is now generally admitted by geologists, that the temperature of the earth was at a former epoch much higher than at present, at least that it was so in northern latitudes. The facts on which this opinion is founded are very numerous, but they are chiefly dependent on the organic remains found in a fossil state. The animal remains of the large mammalia, such as the elephant, the rhinoceros, the hippopotamus, are abundant in some of the tertiary and diluvial beds. The bones and teeth of elephants in Siberia, and the borders of the Icy Sea, are so numerous, that it is evident the animals must once have existed in immense multitudes in these high latitudes. On the Oyster Bank, off Hasburgh, on the Norfolk coast, many hundred grinders of elephants have been found, and a vast quantity of their bones. (*S. Woodward's Syn. Tab.*) Teeth of the elephant have also been found in almost every county in England, and in all the northern kingdoms of Europe. Remains of lizards of enormous size occur in many of the English strata: these animals, in a peculiar manner, seem to require a high temperature for their full development.

The fossil remains of vegetables, prove the high temperature of the countries in which they flourished, more decidedly than animal remains. Fossil trunks and leaves of the palm tree, the tree-fern, and of gigantic reeds, analogous to what are now growing in equatorial climates, abound in the coal strata of northern latitudes. It may be objected, that the large mammalia, (such as the elephant or hippopotamus,) belong to the order of Pachydermata, or thick-skinned animals, and like the pig, which belongs to that order, might be constituted for living both in polar and equatorial regions. Indeed it is known that some of the fossil elephants had a covering of hair or wool, which must have been intermixed as a defence against cold. A race of elephants with shaggy hair (according to Bishop Heber) inhabits the cool regions of the Himmelaya mountains. From the remains of these large mammalia alone, we could not therefore prove the high former temperature of northern latitudes. But these animals would require a constant supply of food throughout the year, which they could scarcely obtain in a frozen climate; and when we farther observe, that the vegetation of the ancient world was analogous to the vegetation of the warm regions which the elephant and

the rhinoceros now chiefly inhabit, we can scarcely refuse our assent to the position, that the temperature of the earth at a former period, was much higher than at present. In addition to this, we have in our strata, the fossil bones of enormous amphibious reptiles, and the shells of marine animals like the nautili, that exist at present in equatorial seas: we thus obtain an accumulation of evidence, both from the water as well as the land, in proof of the same position.

The present temperature of the earth appears to be dependent on two causes,—the radiation of heat from the sun, and internal fire. That the temperature of different latitudes is in a considerable degree dependent on solar radiation will not be disputed: it increases with the increase of the sun's meridian altitude, as we advance towards the equator, and it increases and decreases in the same latitude, with the increase and decrease of the sun's altitude in different seasons. The temperature of different countries in the same parallels of latitude is very much modified by various causes: between the tropics, at the height of about fifteen thousand feet, we meet with eternal snow. In the Swiss and Savoy Alps, the line of perpetual congelation is about seven or eight thousand feet: yet the upper valley of the Rhone, in the canton of the Vallais, surrounded by snow-clad mountains, is subjected to an oppressive heat in the summer months, owing to the stagnation of air in the valley, and the reflection of heat from the rocks.

Large elevated continents in high latitudes, greatly decrease the temperature of the air, by presenting a great surface of snow and ice to the atmosphere. On the contrary, near the equator, large continents raise the temperature, by the constant radiation of heat from the ground. The ocean preserves a more uniform temperature at different seasons than the land; hence, islands surrounded by large seas, possess a more equal temperature throughout the year, than continents in the same latitudes. The lines of equal temperature (called isothermal lines) are not parallel to the lines of latitudes, as they would be, were temperature not affected by the causes before stated. Quebec, with its Siberian winter, is nearly in the same parallel of latitude as Rochelle, in France, and is not two degrees north of the latitude of Bordeaux; a difference not greater than between London and Nottingham, which in this country produces scarcely a perceptible effect on the climate. In some countries, where the summer temperature is much greater than that of other countries in the same parallel of latitude, the average annual heat, or what is called the mean temperature, as measured by the thermometer, is the same in both; because though the summers may be hotter, the winters are proportionally colder, which reduces the average temperature to an equality. But though the mean temperature may be the same,

the greater periodical increase and decrease of temperature in one country than in the other, occasions a considerable difference in the vegetation. If we examine in a good map two situations in the same parallel of latitude, which possess very different degrees of temperature, we may generally observe a variation in the relative proportion of land and water, which may serve in a considerable degree to explain, why one situation should enjoy more heat than the other.

Mr. Lyell has advanced a theory respecting the former high temperature of northern latitudes, in which, by many local illustrations and ingenious arguments, he attempts to prove, that a great change in the relative position of the land and sea, would be sufficient to account for the excess of the former temperature, over that now enjoyed in northern regions. He states two extreme cases, which, could they ever occur, must produce an important change in the climate of Europe. Were the land between the tropics to be submerged under the ocean, and an equal portion of mountainous land to be raised in the polar circles, the cold of those regions would be much increased, and the heat between the tropics would be very greatly diminished; by the joint operation of these causes, the climate of the southern parts of Europe, might become as cold as that of Siberia. On the contrary, were all the land in high latitudes to be submerged, and an equal quantity of land to be raised above the sea, near the equator, the mean temperature of a great part of Europe might be sufficiently increased, to support the vegetation of tropical climates. The theory of Mr. Lyell throws much light on the causes which affect the climate of various countries in the same parallels of latitude; and could we grant that the change of land and sea had ever been so complete as what he has imagined, the conclusions deduced therefrom would be undeniable: but so many conditions are required to effect such extreme changes, that we must regard their occurrence as merely possible; and La Place, in his "*Essai Philosophique sur les Probabilités*," has shewn, that between events which are merely possible, and those which the philosopher should regard as probable, there is an almost immeasurable interval. Nor can the theory of Mr. Lyell be well reconciled with the occurrence of the remains of such immense multitudes of tropical animals and plants, in countries bordering the arctic circle, because, to increase the temperature of Europe in a considerable degree, the theory would require all the land in high northern latitudes to be submerged; but this is precisely the land on which the elephants and other animals lived and have left their remains, and on which tropical plants flourished. To take away this ground in order to increase the temperature, is destroying the very object, for which the theory was invented, and rendering it useless, as an explanation of the former high temperature

of northern latitudes, for it is only by the occurrence of the animal and vegetable remains, that we have any evidence that the former temperature was higher than at present.

The cause which has effected a change in the temperature of the earth, must probably be sought for, either in the earth itself, or in some change in its orbit, or in the relative position of its axis. Did the the severe laws which analysis and observation have established in astronomy, allow the geologist to admit a slow revolution of the globe, round two opposite points of the present equator, each part of the earth would in succession be brought between the tropics; and if we could suppose the axis of diurnal rotation, to preserve the same inclination to the ecliptic as at present, we should have all the conditions required, for explaining the former high temperature of polar regions. The spheroidal form of the globe appears, however, to preclude the admission of this hypothesis; nor does it derive any support, from astronomical observations continued for 2000 years.

Even an increase of the obliquity of the earth's axis to the ecliptic, without any other change, would produce a great effect in the climate of northern latitudes, by increasing the summer heat; but the winters would be colder than at present. There is, indeed, an annual change in the obliquity of the ecliptic, but it appears to be confined within limits, too small to produce a sensible effect on the temperature of any part of the globe. The effects that might be produced by a change of the earth's orbit, remain to be noticed.

A change in the form of the earth's orbit, if considerable, might change the temperature of the earth, by bringing it nearer to the sun in one part of its course. The orbit of the earth is an ellipsis, approaching nearly to a circle; the distance from the centre of the orbit, to either focus of the ellipsis, is called by astronomers the "*eccentricity of the orbit.*" This eccentricity has been for ages slowly decreasing, or in other words, the orbit of the earth has been approaching nearer to the form of a perfect circle; after a long period it will again increase, and the possible extent of the variation has not been yet ascertained.* From what is known respecting the orbits of Jupiter and Saturn, it appears highly probable, that the eccentricity of the earth's orbit, is confined within limits, that preclude the belief of any great change in the mean annual temperature of the globe, ever having been occasioned by this cause.†

* Sir J F. W. Herschel, in a paper on the subject, read to the Geological Society, states that a variation in the eccentricity of the earth's orbit, from the circular form to that of an ellipse, having an eccentricity of one fourth of the major axis, would produce only an increase of 3 per cent. in the mean annual amount of solar radiation.

† Un autre phénomène également remarquablé du système solaire, est le peu d' eccentricité des orbes des planètes, et des satellites, tandis que ceux des comètes

The heat from solar radiation, may possibly have been greater in remote ages than at present. Sir Wm. Herschel inferred, from the variable spots on the sun, that the mean temperature of the earth was increased or decreased in certain years; or, in other words, that the earth received an unequal annual supply of heat from the sun. We have however, no data from whence to ascertain, that there has ever been any considerable change of temperature effected by this cause; to appeal to the high former temperature of the globe in proof of it, would be to substitute vague hypothesis in the place of facts.

Beside solar radiation, it is believed by many philosophers, that there is a source of subterranean heat within the earth itself; this opinion is by no means new, but it appears to have received support from numerous observations and experiments made in a comparatively recent period. The evidence by which the theory of central heat is supported, is derived first, from the occurrence of volcanic fires in almost every degree of latitude north or south: secondly, from submarine volcanoes; thirdly from the occurrence of numerous thermal springs in countries remote from active volcanoes: lastly, from direct experiments made on the temperature of the earth, at various depths in mines, and by sinking and boring into the earth.

Whether there exists a mass of heated matter under the whole surface of the globe may be uncertain; but that there is subterranean fire, under a considerable extent of the surface, can scarcely be doubted. The volcanoes that are thickly scattered over both the northern and southern hemisphere, the long period of their activity, and the connection that appears to subsist between the volcanoes in distant districts, (see Chap. XIX,) prove the depth and extent of the source of volcanic fire. The volcanoes that break out from under the sea, and overcome the vast pressure of the incumbent ocean, farther indicate, that the explosive force is situated at a great depth. Thermal waters, prove the extensive effects of subterranean heat; for though many hot springs rise in volcanic districts, and are properly a part of volcanic phenomena, yet other thermal waters are far removed from any active volcanoes. Some hot springs have flowed without any known diminution of temperature for nearly two thousand years; this is the case with the waters of Bath, which have no volcanoes nearer to them, than those in Iceland and the south of Italy. That thermal waters derive their temperature from a deep-seated internal source of heat, and not from any local cause, or from chemical changes near the surface, is rendered probable by various circum-

---

sont très-allongés. Nous sommes encore forcés de reconnaître ici l'effet d'une cause régulière, le hazard n'eut point donné une forme presque circulaire aux orbes de toutes les planètes et de leurs satellites.—*La Place, sur les Probabilités.*

stances. In many of these waters, there is scarcely any admixture of saline or mineral matter, which there would be, were the heat derived from chemical decomposition. Most warm springs are situated near to crystallized primary rocks, or to basaltic rocks or dykes, as I observed to be the case in the Alps. Hot springs often rise among the loftiest mountain ranges in Asia and America. The temperature of thermal waters in low situations, is frequently reduced by admixture with cool springs near the surface, and this I believe to be the principal cause, why thermal waters so rarely rise in the upper secondary strata, as I have more fully stated in an account of the thermal waters of the Alps. (See *Appendix.*) It could scarcely have been expected, that an enquiry relating to the temperature of the central part of our planet, could be brought within the limits of human observation and experiment, as the depth to which we can explore by boring or by excavation, bears so inconsiderable a proportion to the diameter of the earth; yet from numerous observations on the temperature of the earth in deep mines, and from experiments on the temperature of water at different depths, it would appear, that this temperature increases in a very remarkable degree, as we descend lower from the surface. In France, the subject has been recently investigated with considerable activity; and the practice, which is becoming general in that country, of boring for water, to form what are called Artesian wells, has greatly facilitated the investigation.*

M. Cordier has particularly directed his attention to this subject, and from numerous experiments made by himself and others in mines and Artesian wells, he has drawn the following conclusions:—1st, that there exists a subterranean heat in the terrestrial globe independent of solar radiation, and which increases rapidly with the depth:—2d, that the increase of heat, does not follow the same line in all parts of the earth; indeed, he supposes the differences may be twice or three times as great in one country as in another:—3d, these differences are not in constant relation with the longitudes and latitudes of places where the experiments have been made:—4th, that the heat increases with the increase of depth, in a much greater degree than was previously believed. M. Cordier farther maintains, that there is a source of intense heat in the earth, and that the external crust may be from 50 to 100 miles in thickness, and that all within this crust is a mass of mel-

---

* Boring for Artesian wells has become general in many parts of Italy and Germany. In France, it is found that the average increase of heat, above the mean temperature of the surface, is about one degree of Fahrenheit's thermometer, for every forty five feet in depth; or one degree of the centigrade scale, for twenty five metres: but this is liable to variation of increase or decrease in different situations. For a further account of the temperature of mines and wells, see Appendix.

ted matter: that originally the whole globe was an entire mass of melted matter before the external crust became solid, by throwing out its heat into space; and that, in this manner, the solid crust is constantly growing thicker, and the internal heat diminishing.

We have no very decisive experiments on the temperature of Artesian or other wells in England, but numerous experiments have been made on the temperature both of the air, the water, and the rocks in mines, at different depths; and the general results of each, have indicated a considerable increase of heat with the increase of depth. In Dolcoath copper mine, Mr. Fox found the temperature of the water (at about 480 yards from the surface) to be more than 30° of Fahrenheit above the mean temperature of the country. A thermometer, plunged into the earthy matter, at the bottom of another mine in Cornwall, 400 yards deep, and which had been inundated for two days, was raised 38° above the mean temperature.

Mr. Henwood has made many experiments on the temperature of running streams of water on their issuing from unbroken rock in the Cornish mines, at various depths, both in slate and granite. Probably owing to the influence of surface water, the temperature was but little increased at the depth of near fifty fathoms, below which the thermometer rose considerably.

	Fathoms.	Number of Observations.	Temperature.
Average depth in Slate,	35	21	57°
—	73	19	61°
—	127	29	68°
—	170	21	78°
—	221	5	86°
In Granite, - - -	31	7	51°
—	79	15	59°
—	133	11	63°
—	277	3	81°

At the Lead Hills in Scotland, in mines that had not been worked for several months, nor heated by any fires, Professor Forbes stated to the British Association in 1836, that the temperature of the water was found to increase about 50° of Fahrenheit, for a descent of ninety five fathoms.—Athenæum, Aug. 27, 1836. This extraordinary increase, if correctly given, can only be explained by the operation of some unknown local cause. In some instances, probably owing to other local causes, the increase of temperature at certain depths, is much less than in any of the cases before stated. On the whole, however, the temperature,

though variable in different situations, is found to increase with depth.*

The spheroidal form of the earth, indicates an original state of fluidity, and whatever might be the tenacity of the fluid matter, the rapid rotation of the earth on its axis, would swell out the equatorial parts, and form a spheroid of rotation. Intense heat appears to be the only natural agent we are acquainted with, that could retain the mass of the earth in a fluid state:—farther, the granitic crust of the globe, most probably owes its crystalline structure to slow refrigeration from a state of igneous fusion. Thus both the form of the earth, and the structure of its crystalline crust, are favorable to the theory of central heat. If this theory can be established, it will offer a satisfactory explanation of the former high temperature of the globe, and of its subsequent progressive refrigeration:—also of another circumstance equally remarkable. It would appear, from the fossil remains of vegetables in different latitudes, that every part of the globe once enjoyed nearly the same degree of heat; the cause of this equality must have been independent of solar radiation, and derived from the earth itself. There are certainly numerous circumstances that favor the theory of central heat, but it must be confessed, that it is also accompanied with difficulties not easily to be removed.

If the earth be composed of a solid crust or shell surrounding a fluid mass, this internal fluid would be subjected to the attraction of the sun and moon, or in other words, would have its regular tides. We are not acquainted with any counteracting influence, to prevent the impulse of these tides upon the solid shell. I am, however, fully persuaded, that the internal parts of the earth do not consist of an assemblage of chaotic elements, but that they are arranged with as much wisdom as the parts of the external universe, and that the earth itself is the vast laboratory, in which was prepared, according to definite laws, all the mineral substances found on its surface, and in which are now preparing the elements of future changes.

There is one difficulty attending the theory of central heat, noticed by Professor Sedgwick, which it may be proper to state. "If," says he, "during any period, the earth has undergone any considerable refrigeration, it must also have undergone a contraction of dimensions; and also, as a necessary consequence of a well known mechanical law, an acceleration round its axis: but

* In these experiments, the height of the ground above the level of the sea ought always to be given. A well sunk from the top of a table mountain like Ingleborough, in Yorkshire, which is 800 yards above the level of the sea, would at the depth of 600 yards be still farther from the central heat, than the general surface of the country. I am not aware that this circumstance has been sufficiently attended to, where the depth of the well or mine is stated.

direct astronomical observations prove, that there has been no sensible diurnal acceleration during the last 2000 years; and, therefore, during that long period, there has been no sensible dimunition in the mean temperature of the earth. This difficulty does not, however, entirely upset the previous hypothesis; it only proves, that the earth had reached an equilibrium of mean temperature, before the commencement of good astronomical observations."

If the terrestrial globe has ever been a fluid ignited mass, it is obvious that the atmosphere must have undergone great changes during the progress of refrigeration. In the original ignited state of the earth, all the aqueous particles that form the ocean, and all the more volatile mineral substances, must have existed in the form of vapor, and have constituted a nebulous medium of vast extent, resembling the atmosphere of a comet, or the nebulosity surrounding the newly discovered planets, Juno, Ceres, and Pallas. By progressive refrigeration, the volatile mineral matter would be concreted, and the aqueous particles precipitated, until the constitution of the atmosphere became fitted for the support of animal life. It is not improbable, that the animals of the earliest creation, might have been constituted to breathe a denser atmosphere than the present one. Such an atmosphere would, in a considerable degree, equalize the mean temperature of the earth; and the excess of moisture and of carbonic acid gas, would also be favorable to the rapid development of vegetation.

In stating these hypotheses, my only object has been to suggest to the reader, the various causes which may have affected the former temperature of the globe. I shall leave him to determine how far any of them appear to be supported by analogy and probability.

The original fluidity of the globe appears to be indicated by its present spheroidal form; and in the large planets that compose part of our system, the spheroidal form is more fully displayed, particularly in the planet Jupiter. Now it well deserves attention, that the conditions under which this form was impressed on the earth and planets, cannot recur again by any known causes now in operation, or by any other conceivable cause, except the fiat of the Creator. Thus we are brought at once to a commencement of the series of geological changes, which could not have been the result of any secondary causes, that come within the limit of our present experience. About a century ago it was the fashion among philosophers, to explain all the phenomena of nature, even thunder and muscular action, by the operation of known causes; that is, by the established laws of mechanics, and by chemical fermentation. The discoveries of Franklin and others subsequently proved, that there were more things in heaven and earth than had been dreamed of in past philosophy. It would

indeed, be astonishing if, with our limited powers and ephemeral existence, we should now have discovered all the causes that have effected changes in the former condition of the globe.

> "One part, one little part, we dimly scan
> Through the dark medium of life's feverish dream."

The senses given us by the Creator, as the inlets of knowledge, are sufficient for all the useful purposes of life on our planet; but it would be extremely rash to infer, that they are adequate to discover or to perceive all the properties of matter, or the changes these properties can effect. Some material powers or agents, cannot be made perceptible to any of our senses, except by their effects; such, are universal gravitation, magnetism, and crystalline polarity; and ages had elapsed, before the existence or operation of such powers was even suspected. If we extend our views to the planetary system, we may discover a state of things, which implies that the elementary matter of which planets and satellites are composed, is essentially different from terrestrial matter; and the difference must be such, that it would require an organization and constitution of the inhabitants (if they be inhabited,) altogether so unlike what we are acquainted with, that we are as incapable of forming any distinct idea respecting them, as a blind man is of forming an idea of colors. This may be clearly inferred from the different density of the planets. The density of Saturn is stated by astronomers to be about one tenth that of the earth, or scarcely half the density of pure water. Most of the Saturnian metals and minerals must be lighter than cork wood; and no fluid like water can exist any where but in the centre of the planet. But Saturn has an atmosphere and variable clouds or belts; it must therefore have a fluid on its surface, that performs the functions of water; yet this fluid must be chemically and essentially different from water, or from any fluid on our earth. The properties of matter, and the laws of definite proportion, cannot be the same on Saturn as upon the earth, and it is highly probable, that different senses would be required, to make these properties perceptible. If from the body of Saturn we turn our attention to the double ring by which it is surrounded, we must admit a former condition of that planet, which can never return, by any known secondary causes in present operation. Thus both geology and astronomy lead us to acknowledge a first Almighty cause, and a commencement of the present order of things, dependent upon his will.

In offering the preceding remarks, I have not been influenced by a desire to oppose the opinions of others, but to support what appears to me to be the truth.

I shall now take leave of the reader in the words with which the former editions were concluded.

It may be right to advert to an inquiry that has frequently been made—*What advantage can be derived from the study of geology?*

The value of every science must ultimately rest on its utility: but in making the estimate, we ought not to be guided alone by the narrow view of immediate gain. The material universe appears destined to answer two important purposes: the first of which is to provide for the physical wants of its various inhabitants. Now in relation to this purpose, the science which teaches us the structure of the earth, and where its mineral treasures may be found, can scarcely be deemed devoid of utility, by a nation deriving so much of its comfort and wealth from its mineral resources. But beside supplying our physical wants, the external universe is destined to answer a nobler purpose; its various objects appear intended to excite our curiosity, and stimulate our intellectual powers, to the discovery of those laws by which the successive events we observe in nature are governed. Without this excitement, man would for ever remain the mere creature of animal sensation, scarcely advanced above the beasts of the forest, and the universe would be to him a mute and unmeaning succession of forms, sounds, and colors, without connection, order, or design. In those sciences which have attained the highest degree of perfection, the skill of the Creator, and the ends and uses of the different parts are most apparent. Geology has not yet made sufficient progress to carry us far in this path of enquiry; but we see enough to discover, that the apparent disorder into which the strata on the surface of the globe are thrown, and the inequalities which it presents, are absolutely necessary to its habitable condition. The distribution of its mineral treasures, and particularly of coal, to the cold and temperate regions of the globe, is well deserving attention, and implies a prospective regard for the wants of civilized man: but a cold hearted philosophy, under the sanction of a quaint expression of Lord Bacon,* has, (to use the words of Dugald Stewart) "made it fashionable to omit the consideration of final causes entirely, as inconsistent with the acknowledged rules of sound philosophizing. The effect of this has been to divest the study of nature of its most attractive charms, and to sacrifice to a false idea of logical rigor, all the moral impressions and pleasures, which physical knowledge is fitted to yield."

Geology discovers to us proofs of the awful revolutions which have in former ages changed the surface of the globe, and overwhelmed its inhabitants; it reveals to us the forms of strange and unknown animals, and unfolds the might and skill of creative

* "Causarum finalium inquisitio sterilis est, et tanquam virgo Deo consecrata nihil parit."

energy, displayed in the ancient world: indeed, there is no science which presents objects that so powerfully excite our admiration and astonishment. We are led almost irresistibly to speculate on the past and future condition of our planet, and on man its present inhabitant. What various reflections crowd upon the mind, if we carry back our thoughts to the time when the surface of our globe was agitated by conflicting elements, or to the succeeding intervals of repose, when enormous crocodilian animals scoured the surface of the deep, or darted through the air for their prey;—or again, to the state of the ancient continents, when the deep silence of nature was broken by the bellowings of the mammoth and the mastodon, who stalked the lords of the former world, and perished in the last grand revolution, that preceded the creation of man. Such speculations are somewhat humbling to human pride on the one hand, but on the other, they prove our superiority over the rest of the animal creation; for it has been regarded by the wisest philosophers in ancient times, as a proof of the high future destiny of man, that he alone, of all terrestrial animals, is endowed with those powers and faculties, which impel him to speculate on the past, to anticipate the future, and to extend his views, and exalt his hopes, beyond this visible diurnal sphere.

The following observations on the study of geology, taken from Professor Sedgwick's truly eloquent address to the Geological Society of London, in 1831, are so just and beautiful, and are so closely related to what I have before stated, that I am certain my readers will be highly gratified by their insertion.

"If I believed that the imagination, the feelings, the active intellectual powers bearing on the business of life, and the highest capacities of our nature were blunted or impaired by the study of our science, (Geology,) I should then regard it as little better than a moral sepulchre, in which, like the strong man, we were burying ourselves and those around us, in ruins of our own creating. But I believe too firmly in the immutable attributes of that Being, in whom all truth, of whatsoever kind, finds its proper resting place, to think that the principles of physical and moral truth can ever be in lasting collision. And as all the branches of physical science are but different modifications of a few simple laws, and are bound together by the intervention of common objects and common principles; so also, there are links, less visible, indeed, but not less real, by which they are also bound to the most elevated moral speculations.

"Geology lends a great and unexpected aid to the doctrine of final causes; for it has not merely added to the cumulative argument, by the supply of new and striking instances of mechanical structure adjusted to a purpose, and that purpose accomplished; but it has also proved, that the same pervading principle, manifesting its powers in our times, has also manifested its power in times long anterior to the records of our existence."

APPENDIX.

A.

AN INDEX OUTLINE OF THE GEOLOGY OF ENGLAND.

The outline of the geology of England, and the map that accompanied it, given in the first and second editions of this work, presented (the author believes) the first distinct general view of the geology of England that had ever been published; and though several parts of our island have since been more fully examined, the examinations have confirmed the correctness of the leading facts, stated in the editions of 1813 and 1815. The author has subsequently revisited a considerable part of England and Wales, and collected materials for a more ample detail of their geology, which at one time he had intended to publish.

This index outline will serve to explain the map and sections, by references to the chapters where the different classes of rock are described.

In tracing the great outlines of the physical geography of continents and islands, we may generally perceive, that they are determined by the ranges of primary and transition mountains that traverse them: these have been compared to the skeletons, on which the other parts of a country are constructed.

The length of Britain is determined by different groups of mountains, which, viewed on a large scale, may be regarded as one mountain range, extending north and south (with its ramifications) along the western side of England and Wales, from Cornwall to Cumberland, and from thence to the northern extremity of Scotland. All the highest mountains in England and Wales are situated in this range, which, in reference to our island, may be called the great Alpine chain. This chain is interrupted by the intervention of the Bristol Channel, and again by the low grounds of Lancashire and Cheshire, which divide it into three groups or ranges; these, for the sake of distinction, may be denominated the Devonian range, the Cambrian range, and the Cumbrian or Northern range. They form the *Alpine districts* of England (colored red in the map.) The mountains of the great Alpine chain from Cornwall to Cumberland, are composed of primary rocks and of other rocks, which belong chiefly to the class of transition rocks, described in Chap. V, VI, and VII. Those parts in which the primary rocks chiefly occur, are shaded by lines. In some few parts, east of the Alpine district, the primary and transition rocks also make their appearance, uncovered by the secondary strata. A range of primary and transition mountains appears once to have extended from the Devonian range, in a northeast direction, into Derbyshire;—the transition and basaltic mountains of that county, the Charnwood Forest hills, the sienitic greenstone of Warwickshire, the transition rocks of Dudley, the Malvern Hills, and the trap rocks of Gloucestershire, Somersetshire, and Devonshire, were probably parts of one range, and were much loftier than at present. It may deserve notice, that the granitic

rocks, in this range, are closely allied to rocks now generally supposed to be of igneous origin.

It was this northwest range, that appears to have determined the extent of our island in that direction, and to have formed the western border of an ancient sea or lake, in which the upper calcareous strata of the midland, eastern, and southern counties were deposited. It also appears to have determined the extent of the upper calcareous strata, that cover the eastern side of England, and are bounded by the line A A A. This boundary marks the direction of a range of calcareous hills, that extends through England in a waving line, from the western extremity of Dorsetshire to the eastern side of the county of Durham. East of this line, there are no beds of good mineral coal in any part of England. Between the line A A A and the Alpine districts (colored red,) we have the under secondary strata (colored green.) All the principal coal formations in England occur in different parts of this district, which, for the sake of distinction, we shall call the *middle district* :* it is, however, partly covered by beds of red marl and sandstone. *The upper calcareous district*, east of the line A A A (and colored yellow in the map,) is in some parts covered with beds of clay and sand of a more recent formation, belonging to the tertiary strata: they are colored brown, and are bounded in the map by the lines o o o o. Other lower parts of this district are covered by alluvial depositions, and marked 1 1 1. The upper calcareous formations, colored yellow, are described in Chaps. XIII, XIV, and XV. The tertiary beds are described in Chaps. XVII and XVIII.

England and Wales may thus be divided into three geological districts: the Alpine district, consisting of primary and transition rocks,—the Middle district, comprising the coal formation and the secondary strata of new red sandstone,—and the Upper Calcareous district, comprising the lias, the oolite and chalk formations; the latter partly covered by tertiary formations. Each of these districts has its appropriate characters and mineral productions. In order to give the reader a clear idea of the relative position of the rocks and strata of these three divisions, let him take three sheets of paper, and cut out the form of England in each. Let the lower sheet be red; cover this with green paper, cutting out all the parts on the western side, which will leave the parts marked red in the map uncovered, and also the small parts where the Malvern Hills and Charnwood Forest hills are situated. Cut out the third sheet of yellow paper, so that its edge may correspond with the line A A A. Then cut out pieces of darker colored paper, and place them over the parts marked 2 2 2, for the tertiary strata; and place dark patches on the parts marked 1 1 1, for alluvial and diluvial depositions; raise the western edge a little, so as to make the sheets of paper incline to the southeast;—and we shall then have a model of the geology of England, which would be more complete, provided we could raise the parts marked red above the level of the green paper. The red paper, which spreads under the whole, and represents the primary and transition rocks of the Alpine districts, may be conceived to extend under the sea, and to rise again in Ireland, France, Sweden, and Germany, and thus to be connected with all the granitic ranges of

* The coal formation may be classed with the upper series of transition beds; but its mineral characters, and its terrestrial and fresh-water organic remains, may properly entitle it to form a separate geological division.

the old continent. It is scarcely requisite to remark, that, in presenting a general view of the arrangement of the different classes of rocks in this manner, the partial wavings or irregularities of the strata, and the inequality of surface, presented by hills and valleys, must be necessarily disregarded.

The primary rocks of England and Wales are described in various parts of Chaps. V, and VI, in the present volume. The transition rocks, including mountain limestone, are described in Chap. VII. The coal formations in England, within the middle district, (colored green in the map,) extend on the eastern side of Northumberland and Durham, from Berwick-on-Tweed to the river Tees; but from thence to the river Air, (near Leeds,) only the lowest beds of the coal formation occur, which contain but little workable coal. The Yorkshire and Derbyshire coal-field commences a little north of Leeds, and extends in breadth east and west about twenty-five miles, from Halifax to Abberford, and in length about seventy miles, from Leeds to near Nottingham and Derby. The breadth decreases southward, being little more than twelve miles in Derbyshire.

Southwest of Derbyshire, there are a few small coal fields near Ashby-de-la-Zouch, and near Tamworth, Atherstone, and Coventry. The latter coal field is the most southern situation in which mineral coal has been discovered in the midland counties.

On the northwest side of England, there is a small coal field bordering the sea in Cumberland, which extends from Whitehaven to the north of Maryport. This coal field, though small in extent, contains seven beds of excellent workable coal. From its contiguity to the sea, and its remoteness from other coal fields, it may be considered, in proportion to its extent, as one of the most valuable coal districts in England. In one mine, the coal is worked at the depth of 298 yards. The workings of some mines have been extended under the sea. The next considerable coal field is that of Lancashire: it is separated from the Yorkshire coal field by a range of lofty hills, on the borders of the two counties, extending, on the west side of Colne, to Blackstone Edge, and from thence to Axe Edge, on the border of Derbyshire. These hills are principally composed of millstone grit and shale, but are not covered by coal strata. On the western side of these hills, the coal strata of the Lancashire coal field commence, dipping westward; but they are broken and deranged by numerous faults. The principal beds of coal are,—one of six feet in thickness, and a lower one called the three-quarter bed. In some parts, the sandstone strata are of a deep red color. The breadth of this coal field, from Macclesfield to Oldham, does not exceed five or six miles; but from Oldham it extends westward to Prescot, near Liverpool, and from Prescot it extends in a northeast direction to Colne.

Not far from the southern extremity of the Lancashire coal field, there is a small but valuable coal district, which supplies the potteries near Newcastle in Staffordshire: this may properly be considered as an extension of the Lancashire coal field. The next important coal field is that of Dudley and Wolverhampton: it is about twenty miles in length, and varies in width from four to seven miles. It contains the thickest bed of coal in Great Britain. (See page 119.) There is a narrow coal field on the northeastern border of Wales, extending from Mostyn, in Flintshire, to Chirk, in Denbighshire. There are, also, a few smaller coal fields on

the northeastern side of Herefordshire, which extend into Shropshire. The Clee Hills, near Ludlow, contain, on their sides, two or three small detached coal basins. The summits of these lofty hills are capped with basalt.

The coal basin of the Forest of Dean, is the next considerable repository of coal: it presents, perhaps, the most perfect model of a coal basin of any in Great Britain; the coal strata occupy a space of about ten miles in length, and six in breadth: the millstone grit and the transition limestone on which they lie, may be distinctly observed cropping out, on its northern and western boundary.

In Somersetshire and Gloucestershire, there is a considerable coal field on each side of the river Avon; its greatest extent is about twenty miles, and its greatest ascertained breadth about eleven miles; but it is covered in many parts by the secondary strata, consisting of red marl and lias. The deepest coal mine in England, is in this coal field; the depth of the pit at Redstock, near Bath, being 409 yards.

The greatest repository of coal in our island, is that which extends on the northern side of the Bristol Channel, 100 miles in length, and varying in breadth from five to twenty miles, pages 117, and 118. Further information respecting many of the English coal fields will be found in Chapter VIII.

A considerable part of the middle district, (colored green in the map,) which is not occupied by the coal formations above enumerated, is covered by the red marl and sandstone, described in Chapter XII. As the sandstone of this formation often covers the coal strata, it becomes an object of great interest to landed proprietors in the midland counties, who have estates at no great distance from the coal districts, to ascertain whether coal may not extend under the red marl and sandstone. Some observations on this subject are given, (pages 132, and 133,) which the author is persuaded deserve the attention of landed proprietors. The search for coal under the red marl and sandstone in Somersetshire has been eminently successful; and coal has in some instances been found, by sinking through both lias and red sandstone.

The principal repositories of rock salt, and the strongest springs of brine, are situated in the red marl of Cheshire, and near Droitwich, in Worcestershire. (See pages 201, and 202.) In this formation the principal beds of gypsum are found: it is frequently associated with rock salt. (See Chapter XII.)

One of the most remarkable features of the middle district, is the occasional occurrence of various rocks (*in situ*) of granite, slate, and sienite, belonging to the class of primary or transition rocks; they rise through the secondary strata, and appear, from various circumstances, to have once occupied a considerable portion of the midland counties, extending from Leicestershire to Warwickshire, Worcestershire, Gloucestershire, Somersetshire, and Devonshire. The secondary strata of England, from lias to chalk, (colored yellow in the map,) are pretty fully described in Chapters XIII, XIV, and XV. The more recent or tertiary strata (colored brown in the map, and marked 2 2,) are described in Chaps. XVII, and XVIII. The basalt dyke of Cleveland, which runs through the North Riding of Yorkshire into Durham, is described, with other basaltic rocks in England, in Chapter X, and the alluvial beds, marked 1 1 1, are described in Chapter XXII. A description of many of the mining dis-

tricts of England and Wales, will be found in the chapter on metallic veins.

It now remains to notice the sections in different parts of England. A section, to possess much value, should be made as nearly as possible along the true line of the dip and rise of the strata. We possess no true line of dip in England, which passes through all the different classes of rock; and it is only misleading the reader, to represent the succession of rocks out of their true situation. The section of the secondary strata, with a small portion of the tertiary, given at page 167, represents the succession of the different secondary formations, from chalk to the lowest new red sandstone, taken in a line from the chalk hills northwest of London, to the transition rocks south of the Malvern Hills, in Herefordshire. But in this line, the lower red sandstone, and magnesian limestone are wanting.

If we draw another line across England, through Durham and Cumberland, from the German Ocean, near Sunderland, to the Irish Channel, (see the section, Plate VII,) we may observe the magnesian limestone A forms the uppermost rock of the series; all the secondary strata above this formation are here wanting; it is, however, probable, that they may once have extended into the German Ocean, in the order represented at page 167. The magnesian limestone A, lies unconformably upon the coal strata, which rise to the west, B B; at X the strata are broken by the Burtreeford Basalt Dyke. C C represents the lower beds of the coal strata, with mountain limestone; they terminate at the mountain called Cross Fell, 5. The lower part of this mountain is composed of mountain limestone and greywacke; a little to the west, the beds are broken, by nearly vertical beds of trap and sienite. In the Vale of Eden is Penrith Beacon, 4. This vale is covered by beds of conglomerate and red sandstone. The lofty mountains, E E, that surround the lakes of Cumberland and Westmoreland, are skirted by beds of mountain limestone; but the higher mountains are chiefly composed of slate, felspar porphyry, and greywacke. Granite occurs at the base of Skiddaw and Saddleback, and at Coldback Fell. 1, is Sea Fell, the highest mountain in this group; 2, Skiddaw; and 3, Helvellyn. Farther west we come upon the coal strata of Whitehaven, dipping west, and covered by unconformable secondary strata. Some of the more remarkable rocks in the mountains round the lakes, are described in Chap. VII. Plate II, fig. 4, represents the arrangement of the strata in the central part of England, passing in a line nearly east and west, through the low granite range at Charnwood Forest, in Leicestershire; *e*, on the right hand side of the plate, represents lias, resting on red marl and sandstone, *a*. The granite and slate rocks are represented *b b c c*, partly covered by horizontal beds of red marl and sandstone; *d d* are the coal strata, near Whitwick, much elevated as they approach the Forest Hills. A little out of the line of section, are represented the elevated beds of mountain limestone at Breedon and Clouds Hill, part of which limestone is continued to the Forest Hills at Grace Dieu. For a more particular account of this section, see Chaps. XI, and XXIII; and for an account of the sections near Dudley, in Staffordshire, see Chap. VII.

This brief sketch of the geology of England, with the references to the map, sections, and chapters in this volume, may suffice to give the reader, a general view of the geology of England, and the situation of its principal mineral repositories. I shall subjoin an account of the thermal

waters of England, and of a few celebrated thermal waters on the Continent, and a table of the height of mountains.

Temperature of the Thermal Waters in England, and some other Parts of Europe.

	Fahrenheit.
Bristol	74°
Matlock	66
Buxton	82
Bath	112° and 116
Vichy (Auvergne)	120
Carlsbad (Bohemia)	165
Aix la Chapelle (Flanders)	143
Aix les Bains (Savoy)	117
Leuk (in the Haut Valais)	117° to 126
Barèges (South of France)	120

For an account of the thermal waters in the Alps, see p. 447.

B.

HEIGHT OF MOUNTAINS.

Height of some of the most remarkable Mountains and Hills in England and Wales.

	Feet.
Arbury Hill, Northamptonshire,	804
Arran Fowddy, Merionethshire,	2955
Arrennig, Merionethshire,	2809
Axedge, Derbyshire,	1751
Bagshot Heath, Surrey,	463
Beacons, Brecknockshire,	2862
Bardon Hill, Leicestershire,	853
Beachy Head, Sussex,	564
Black Down, Dorsetshire,	817
Bottley Hill, Surrey,	880
Bow Fell, Cumberland,	2911
Broadway Beacon, Gloucestershire,	1086
Brown Clee Hill, Shropshire,	1805
Cader Ferwyn, Merionethshire,	2563
Cader Idris, Merionethshire,	2914
Caermarthen Vau, Caermarthenshire,	2596
Cam Fell, Yorkshire,	2245
Capellante, Brecknockshire,	2394
Carnedd David, Caernarvonshire,	3427
Carnedd Llewellyn, Caernarvonshire,	3469
Carraton Hill, Cornwall,	1208
Cheviot, Northumberland,	2658
Coniston Fell,	2577
Cordon Beacon, Devonshire,	1792
Cradle Mountain, Brecknockshire,	2545
Cross Fell, Cumberland,	2901
Crowborough Beacon, Sussex,	804
Dichling Beacon, Sussex,	858
Dover Castle, Kent,	469
Dundry Beacon, Somersetshire,	1668
Dunnose, Isle of Wight,	792
Dwggan, near Builth, Brecknockshire,	2071
Epwell Hill, Oxford,	836
Fairlight, down Sussex,	599
Farley Down, near Bath, Gloucestershire,	700
Firle Beacon, Sussex,	820
Grasmere Fell, Cumberland,	2756
Greenwich Observatory, Kent,	214
Hampstead Heath, Middlesex,	427
Hathersedge, Derbyshire,	1377
Hedgehope, Northumberland,	2347
Helvellyn, Cumberland,	3055
Hensbarrow Beacon, Cornwall,	1034
Highclere Beacon, Hampshire,	900
High Pike, Cumberland,	2101
Holme Moss, Derbyshire,	1859
Holyhead Mountain, Anglesea,	709
Ingleborough Hill, Yorkshire,	2361
Inkpen Beacon, Hampshire,	1011
Kit Hill, Cornwall,	1067
Leith Hill, Surrey,	993
Landinan Mountain, Montgomery,	1898
Llangeinor Mountain, Glamorganshire,	1859
Long Mount Forest, Shropshire,	1674
Long Mountain, Montgomeryshire,	1330
Lord's Seat, Derbyshire,	1715
Malvern Hill, Worcestershire,	1444
Moel Fammau, Denbighshire,	1845
Nine Standards, Westmoreland,	2136
Orpit Heights, Derbyshire,	980
Pendle Hill, Lancashire,	1803
Penmaen Maur, Caernarvonshire,	1540
Pennigent Hill, Yorkshire,	2270
Pillar, Cumberland,	2893
Plynlimmon Mountain, Cardiganshire,	2463
Radnor Forest, Radnorshire,	2163
Rippon Tor, Devonshire,	1549
Rivel Mountain, Caernarvonshire,	1866
Rivington Hill, Lancashire,	1545
Rodney's Pillar, (Base of,) Montgomery,	1199
Roseberry Topping, Yorkshire,	1022
Rumbles Moor, Yorkshire,	1308
Saddleback, Cumberland,	2787
Sea Fell (High Point,) Cumberland,	3166
Shooter's Hill, Kent,	446
Shunnor Fell, Yorkshire,	2329
Skiddaw, Cumberland,	3022
Snea Fell, Isle of Man,	2004
Snowdon, Caernarvonshire,	3571
Stow Hill, Herefordshire,	1417
Stow-on-the-Wold, Gloucestershire,	883
Tregarron Down, Cardiganshire,	1747
Wendover Down, Buckinghamshire,	905
Whernside, in Ingleton Fells, Yorkshire,	2384
Whernside, in Kettlewell Dale, Yorkshire,	2263
White Horse Hill, Berkshire,	893
Wrekin, Shropshire,	1320

Mountains in Scotland.

Of the height of the mountains in North Britain, I believe there have not hitherto been any very accurate admeasurements taken. The following are some of the most considerable, with the heights as given by different writers :—

	Feet.		Feet.
Arthur's Seat, Edinburgh, - -	810	Schehallien, - - -	3281 or 3564
Salisbury Craigs, - - - -	550	The most southern of the Paps of Jura, - - - - - -	2359
Hartfell, Dumfries-shire, (supposed by Mr. Jameson the highest in the south of Scotland,)	2800 or 3304	Mount Battock, Kincardineshire,	3450
Goatfield, Island of Arran, - -	2945	Cairngorum, - - - - -	4050
Benlomond, Stirlingshire, - -	3262	Ben-Nevis, Inverness-shire, -	4380
Benlawers, Perthshire, - -	4051	Macdui, in the Grampians, is stated, by late admeasurements, to be 60 feet higher than Ben-Nevis.	
Ben More, Perthshire, - -	3870		

Highest Mountains in the Pennine Alps.

Mont Blanc, - - - - -	15,534	Aiguille d'Argentière, - -	13,370
Mont Cervin, or the Matterhorn,	15,105	The Buet, - - - -	10,112
Monte Rosa, - - - - -	15,410	Dent du Midi, - - - -	10,500
Aiguille de Géant, - - -	13,984		

Highest Mountains in the Swiss Alps.

The Finesterahorn, - - -	14,307	The Eiger, - - - -	12,520
The Jungfrau, - - - -	13,185	The Monch Eiger, - - -	12,900
The Schreckhorn, - - -	12,872	The Wetterhorn, - - -	12,130

N. B. All these mountains are seen from the churchyard at Berne.

Highest Mountains in other parts of Europe.

Northern Pyrenees, - - -	11,160	Mont Mézin, the Cevennes, in France, - - - - - -	6700
Mount Perdu, ditto, - - -	10,950	Mont d'Or, ditto, - - -	6180
Vigne Male, ditto, - - -	10,945	Cantal, ditto, - - - - -	6150
Le Cylindre, ditto, - - -	10,880	Puy de Dôme, ditto, - - -	4750
Ætna, Sicily, - - - - -	10,590	Vesuvius, Naples, - - -	3900
Le Gran Sasso, in the Apennines,	8455	Mount Athos, in Greece, - -	6780
Mont Velino, ditto, - - -	7860		
Loucyra, in Dauphiné, - - -	13,548		

Very few mountains in Europe, north of the Alps, exceed the height of 6000 feet. Some of the mountains in the chain that separates Norway from Sweden rather exceed that height.

Lowest Line of Eternal Snow.

At the Equator, - - - -	15,720	In Switzerland, - - - - -	8000
Latitude 20°, - - - - -	15,000	Latitude 65°, - - - - -	4800
——— 45°, - - - - -	8200		

Passages of the Alps which lead from Germany, Switzerland, and France, into Italy.

Passage of Mont Cervin, (only practicable on foot,) - -	11,200	The Little St. Bernard, - -	7200
Of the Furka, - - - - -	8300	Of St. Gothard, - - - - -	6780
The Grand St. Bernard, - -	8150	Of Mont Cénis, - - - - -	6750
The Col de Ferret, - - -	7600	Of the Simplon, - - - - -	6610
		The Col de Tende, - - - -	5880

Passages in the Pyrenees.

Port d'Or, - - - - - -	9850	Port de Cavarnie, - - - -	7650
Port Viel d'Estambé, - - -	8400	Passage de Tourmalet, - -	7130
Port de Pinède, - - - - -	8200		

Passages in Switzerland.

	Feet.		Feet.
The Wengen Alp,	6750	The Sheideck to Meyringen,	6500

Mountains in Asia.

The Himmalaya Mountains, in Thibet, are the highest at present known, except two in Upper Peru, which, according to Mr. Pentland, possess an equal altitude. According to Dr. Gerard, in the Valley of Sulei, among the Himmalaya Mountains, there is one village 14,700 feet above the level of the sea. These mountains are pastured by the Thibetian goat. Crops of rye are grown at the elevation of 14,900 feet.

Himmalaya Mountains, from	20,000 to 25,000	Lebanon,	9500
Elbourz, in the chain of the Caucasus,	18,500	Mount Sinaï,	5000 to 6000
		Several Islands in the Indian Ocean,	10,000 to 13,000

Mountains of Africa.

The geography of Africa is too little known to afford any correct account of its mountains: those of Abyssinia have been estimated to be equal in height to the Alps, and the chain of Mount Atlas to equal the Pyrenees.

The Peak of Teneriffe, - - 12,236 feet.

South America.

Chimborazo, Quito,	22,700	*Sorate,	25,400
Cotopaxi,	20,320	Antisana, Peru,	20,680
*Illimani,	24,350	Pic d'Orizaba, Mexico,	17,368

Some very lofty mountains rise on the western coast of North America; but few of the mountains in the Apalachian chain, or the Alleghany on the eastern side, rise 3000 feet above the level of the sea.

Highest habitable Parts of the Globe.

The Farm of Antisana, Peru,	13,200	*Titiaca Lake,	12,760
City of Micuipamha,	11,850	*Post-house of Titiaca,	14,402
City of Quito,	9520	City of Mexico,	7400
*City of Puno,	12,830	Hospice of St. Gothard, in the Swiss Alps,	6790
*Potosi Town,	13,350		
*——— Mines,	16,080		

The mountains and towns marked *, are situated in a chain of the Andes, in Upper Peru, interior to the great western chain, and distant from the Pacific 350 miles or more. The table land between the two chains is covered with crops of maize, barley, and wheat. In this table land is situated the Lake of Titiaca.

C.

ON THE THERMAL WATERS OF THE ALPS.

This paper was published by the Author in the "Philosophical Magazine and Annals," January, 1827; and a nearly similar account was given in his "Travels in the Tarentaise," in 1823. The thermal waters of the Alps had before been regarded as merely local and unconnected phenomena, scarcely deserving the notice of geologists.

When we approach a range of lofty mountains, like that of the Pennine Alps, and observe the calcareous strata on the outer part of the range bent and contorted in various directions; when we further observe beds of limestone and pudding stone alternating and placed in an elevated position, as we advance to the central part of the range; and that the beds of granite in the central part are frequently vertical; we feel assured that their present contorted or vertical position, is not the original one. The opinions of geologists have been much divided respecting the cause or causes that have elevated mountains, and given a vertical position to beds that once formed the bottom of the ocean. Those who maintain that subterranean heat has expanded and broken the solid crust of the globe, and has raised from vast depths the ancient bed of the ocean, appeal to a cause that is known to exist, and which seems sufficient to explain most of the various appearances which Alpine regions present.

In opposition to this theory, it is asserted that there are no remaining vestiges of the action of subterranean fire in the Alps: but this I am convinced is erroneous. It is true that from near the source of the Rhone, to the foot of the Little St. Bernard, there does not occur any known rock of a volcanic character with the doubtful exception of some rocks in the valley of Sass, and in the Valorsine. I have examined various parts of this range on the northern side of the highest mountains in the Alps, along a line of one hundred and twenty miles; and though I could discover no indications of the action of subterranean heat in the rocks themselves, I was greatly surprised to observe the numerous thermal springs that are abundantly gushing out at the feet of the primary mountains, near the junction of the mica slate, or the dark schist, passing into the mica slate, with the lowest calcareous beds of that vast series of limestone strata, which forms the outer ranges of the Alps. Numerous as these hot springs are on the northern side of the Alps, and not unfrequent on the southern side also, it appeared to me remarkable, that they had hitherto been regarded as isolated phenomena; and that their geological position had not been noticed. It is true, that some of the warm springs in the Valais and Savoy had been long known and visited, but the greater number has been discovered since Saussure published his *Voyages dans les Alpes;* and it appears probable, that they would every where be found near the junction of the primary and secondary rocks, were it not for *éboulements* that have covered them with a heap of ruins, or that torrents from the glaciers have mixed with them, and reduced their temperature. Since I visited Savoy in 1821 and 1822, another considerable warm spring has been discovered near the village of Chamouni, at the foot of a glacier; and in 1820, several thermal springs were discovered in that branch of the Alps which extends to Grenoble.

I shall here briefly enumerate the principal known thermal waters in the Pennine Alps, and add some observations and inferences, which I trust will be acceptable to several of your readers.

NATERS, *in the Haut Valais.*—The warm spring rises under a rock of mica slate on the north side of the Rhone. The temperature when I visited the place was 86° Fahrenheit; but it is variable, from the intermixture with surface water. At the time of the great earthquake at Lisbon, in 1755, the mountain above the spring, I was informed, opened and threw out a considerable quantity of hot water.

LEUK, *in the Haut Valais,*—situated in a deep gorge on the northern side of the Rhone. There are twelve springs, varying in temperature from 117° to 126°. These springs have been long known, and are visited by patients from various parts of Europe.

THE VALLEY OF BAGNES, *in the Bas Valais.*—The warm springs in this valley were buried under a heap of débris from the fall of part of a mountain, which destroyed the baths, the village of Bagnes, and 120 inhabitants, in the year 1545. The name of the valley is obviously derived from the baths. The temperature of the water unknown.

CHAMOUNI.—The thermal waters at this place have been discovered since I visited Chamouni in 1821. I have received no account of the temperature; baths have recently been erected. The situation is near the junction of mica slate, with the lowest beds of secondary limestone.

ST. GERVAISE,—situated on a deep gorge on the northeast side of Mont Blanc. The thermal water rises near the junction of mica slate and limestone. The temperature 94° to 98°. This spring was discovered about the year 1806: it is very copious. Baths have lately been erected, and are much frequented.

AIX LES BAINS, *in Savoy:*—the temperature from 112° to 117°. The thermal waters rise in great abundance from two springs, situated at the foot of a lofty calcareous mountain, and are near the bottom of the great calcareous formation that forms the outer range of the Alps: there are also numerous hot springs in the vicinity, which the Sardinian government will not allow to be opened. Of the mode of douching at these baths, I have given a particular account in the first volume of my *Travels in Savoy, Switzerland, and Auvergne.* The thermal waters of Aix were well known to the Romans.

MOUTIERS, *in the Tarentaise.*—The thermal waters rise in great abundance from the bottom of a nearly perpendicular mass of limestone. From the position of this rock, and its connection with those on the opposite side of the valley, in which the hot springs rise, I have no doubt that it is the lowest calcareous bed in that part of the Alps; but its junction with mica or talcose slate is not here seen. The thermal waters of Moutiers, contain about two per cent. of saline matter, chiefly common salt. The process of extracting it, I have described in the *Philosophical Magazine,* vol. lxiii. p. 86.

BRIDA, *in the Tarentaise.*—The thermal waters of Brida were noticed in the ancient records of Savoy, but they were covered during a sudden inundation of the valley, and their situation was concealed for many years. In the summer of 1819, another inundation, occasioned by the breaking down of the side of the glacier, laid open the spring again. The rock from which the spring rises is a greenish talcose slate, passing into mica slate; it is in junction with limestone. The temperature of the water is from 93° to 97° Fahrenheit. The geological position of this spring

is more obvious than that of any of the other thermal waters which I visited, being situated close to the steep bank of the river Doron, where both the rocks are laid bare. There are some warm springs on the opposite bank of the river, which rise in limestone: but the temperature is lower, owing to an intermixture with common water.

Saute de Pucelle, or *Virgin's Leap.*—There is a very copious thermal spring rising from the bottom of a perpendicular rock near the Isère, between the town of Moutiers and St. Maurice, at the foot of the Little St. Bernard; but, owing to the difficulty of access to it, I did not visit it, to ascertain its temperature.

Beside the above thermal waters in the Pennine Alps, various thermal springs were discovered in the adjacent Alps, near Grenoble, in the year 1820: and it seems probable, that a series of these springs might be found were proper search made, extending westward to the thermal waters of the Pyrenees; for in this line we should approach the southern border of the volcanic district of France. On the Italian side of the Pennine Alps, there are also thermal waters: the warm baths of Cormayeur and of St. Didier are situated almost immediately under the southern escarpment of Mont Blanc. I was prevented, by the weather, from examining the geological position of these springs; their temperature is stated to be 94° of Fahrenheit.*

The inference that may be drawn from the geological position of these thermal waters near the junction of the calcareous beds with mica slate, or the dark schist which passes into mica slate is, that the waters do not rise from the upper strata, but spring out of the lower or primary rocks; and as they break out near the feet of the highest range of the Alps, that extend from the northern side of the Simplon through the Valais and Savoy into France, we may with much probability infer, that these mountains are situated over or near to one common source of heat, by the agency of which they were originally elevated, and their beds placed in a position nearly vertical. This inference is in some degree supported by the well attested fact, that the districts where the hot springs are situated, are subject to great and frequent convulsions, particularly in the upper valley of the Rhone. In the year 1755, at Brieg, Naters, and Leuk, the ground was agitated by earthquakes every day from the 1st of November, to the 27th of February; some of the shocks were so violent, that the steeples of the churches were thrown down, the walls split, and many houses rendered uninhabitable: many of the springs were dried up, and the waters of the Rhone were observed to boil. At three different times the inhabitants abandoned their houses, and fled for safety into the fields. It has been before mentioned, that the mountain above the warm spring at Naters, opened during the time of the great earthquake at Lisbon, and threw out hot water: at the same period the warm saline springs at Moutiers ceased to flow for forty eight hours. When the water returned, the quantity was said to be increased, and the saline impregnation was weaker. Former and more formidable agitations of the earth are recorded in the Haut Valais, particularly in the district where the principal hot springs are situated. The last earthquake of consequence in the Valais, took place in January, 1803.

* Nearly all the thermal waters in the Alps, emit sulphureous vapors, and are slightly saline, except the waters of Leuk, which have the highest temperature, and are inodorous, and free from saline impregnation.

I am informed that several of the retired valleys on the Italian side of the Alps, at the foot of the central chain, are subject to earthquakes, during which the ground has opened or sunk down in various parts, though these effects have been too local, to excite attention at a distance. From these facts, it seems as reasonable to infer, that the thermal waters of the Alps owe their high temperature to subterranean fire, as that the hot springs in countries that have formerly been volcanic, derive their warmth from an internal, unextinguished, but quiescent, source of heat. No person who has attentively examined the lofty granitic plain to the west of Clermont Ferrand in France, and observed the granite in various parts pierced through by ancient volcanoes, that have poured currents of lava over its surface, or seen other parts, where the granite itself has been changed by its contiguity to subterranean fire, or upheaved and intermixed with volcanic rocks;—no one, I say, who has observed this, can doubt that the hot springs of Mont d'Or and Vichy, derive their high temperature from a source of heat situated beneath the granite mountains, though ages have passed away since the volcanoes of that country have been in an active state, and the only proof of the present existence of subterranean fire in Auvergne, is to be found in the hot springs themselves. Nor can any adequate reason be assigned, for attributing the high temperature of the thermal waters in the Alps to any other cause, than to a source of subterranean fire under these mountains,—a cause which is sufficient also to have produced their original elevation. It is, however, proper to state, that in some of the mountains of the Alps, the temperature may be slightly increased by a cause hitherto unnoticed. In the upper part of the secondary formations covering the granite, there are beds of gypsum, and this gypsum is anhydrous; but when exposed to air and moisture, it combines with water, and passes to the state of common gypsum; during this combination we may suppose heat to be evolved; but the process must be extremely slow, and the heat evolved must be totally inadequate to raise the temperature of powerful streams to 126°. Saussure found the temperature of the water in the lower part of the salt mines of Bex, which are situated in the vicinity of gypsum, to be four degrees of Reaumur higher than the mean temperature of the earth. It is not improbable, though Saussure was not aware of the circumstance, that this small increase of temperature in the mines of Bex, might be partly owing to the combination of water with gypsum: however, an increase of temperature, it is well known, is observed in deep mines, far removed from the gypsum formation.

In reply to what I have advanced respecting the thermal waters in the Pennine Alps, it may be said, that few thermal springs have been yet discovered in the northern range of the Alps which form the Bernese Oberland; but the difference in the geological structure of the two ranges will, I conceive, be sufficient to explain why hot springs are more rare in the latter than in the southern range. Most of the highest mountains in the Bernese Alps are covered with secondary strata; and the valleys are chiefly excavated in these strata, or in enormous beds of sandstone and conglomerate, that form a thick intervening mass between the surface and the primary rocks, sufficient to obstruct the rise of thermal waters; for it has before been stated, that all the thermal waters in the Pennine Alps, issue from the primary rocks, or near their junction with the lowest calcareous strata.

D.

ON THE GREAT WESTERN AMERICAN COAL FIELDS.

THE Valley of the Mississippi contains the largest coal field, or rather collection of coal fields, in the known world; and what is annually taking place in some parts of that valley, appears to confirm, in a remarkable manner, the opinions I have advanced (pages 127, 128) on the formation of coal, and the cause of the frequent recurrence of the same series of strata at different depths, in the same mine; which I attribute to the periodical filling and desiccation of lakes. In the second volume of Mr. Stuart's interesting "Travels in the United States," there is a very instructive account of the Valley of the Mississippi, quoted from an American review. I shall here insert the parts immediately connected with the present subject:—

"What is called the Valley of the Mississippi is not in reality a valley, but an extensive elevated plain, without hills or inequalities deserving notice. It extends west from the western slope of the Alleghany Mountains, to the sand plains near the Missouri, a distance of about 1500 miles, and south from the valley of the northern lakes, to the mouth of the Ohio, about 600 miles. No part of the globe possesses such an extent of uniform fertility. The difference in elevation is only a few feet, as ascertained by actual survey. The general elevation of this plain, is about 800 feet above the sea. It is crossed by the great rivers Missouri, Mississippi, Ohio, and their branches. As we go westerly up the Missouri, and Arkansas to the sand plains, we find nearly the same elevation. The great and numerous rivers that cross this plain, instead of forming valleys, do but indent narrow lines or grooves into its surface, hardly sufficient to retain their floods. As the currents of these rivers roll on in their courses, they sink deeper into the plain; hence the large rivers Ohio, Missouri, and others, seem bordered with hills of several hundred feet elevation, towards their mouths; but the tops of these hills are the level of the great plain.

"The base of this whole extent of plain appears to be transition or mountain limestone, in nearly horizontal beds: it has been perforated to the depth of 400 and 600 feet. It contains trilobites, orthoceratites, the productus, and other fossils that characterize the transition limestone. The uppermost stratum of limestone is not many feet below the surface, and supports, nearly over its whole extent, strata of bituminous coal and saline impregnations. The limestone extends under the Alleghany Mountains in the east, and the sand plains on the west, and rests on the granite ridges of Canada on the north.

"This coal field would cover half of Europe, having an extent of 900,000 square miles; or 1500 miles in length, by 600 miles in breadth. The coal is pure, and lies above the beds of the rivers, and costs about twenty cents (the fifth part of a dollar) per ton to quarry it. Iron ore abounds generally, but in Missouri there is a mass of this ore 300 feet in height, and five miles in extent, which yields 75 per cent. of fine mallea-

ble iron. The lead districts of Missouri and Illinois cover 200 square miles." It is not mentioned in the above account, but there can be no doubt, that the mines are situate in the limestone, which identifies that formation still farther with the mountain limestone of England.

"In the geological position and physical structure of this vast coal field, we may, I think, trace, in a satisfactory manner, the mode of its formation. Were the outlet of the waters that drain this large surface to be only partially closed (as we may suppose the mouth of the Mississippi to be) by an earthquake or upheaving of the surface, then in the time of annual periodical inundations, the whole extent of this level plain would be covered with fresh water, and form an inland sea, which would gradually become dry as the inundations subsided. This plain would then become a vast swamp, suited for the rapid developement of vegetation. In this manner thick beds of decomposed vegetable matter might every year be formed, and subsequently covered with strata of mud and earthy matter, deposited during the inundation.

Now let us advert to what actually takes place in the lower valley, or plain of the Mississippi, every year. When those mighty rivers, the Mississippi and Missouri, are inundated, by the melting of the snow near their sources, they pour down immense floods; which fill their banks, and absolutely choke up the mouths of the large secondary rivers that enter them, and throw their waters back for many miles, charged with the mud of the great descending waters. The waters of these secondary rivers in their backward course, overflow their banks, and spread over the lower parts of the level plain, forming lakes of twenty miles or more in length: after some time these lakes are gradually drained by the subsidence of the rivers. The inundations are however, prolonged by another circumstance. The Missouri and Mississippi rise in different latitudes, and their periodical inundations do not take place at the same time. When one of these mighty streams is inundated, it blocks up the passage of the other, and this reacts on the secondary streams, and prolongs the time of periodical inundation. Thus in these temporary lakes of fresh water, we have the conditions required for the formation of future coal fields, swamps promoting the rapid development and decomposition of vegetables, and periodical inundations of water, charged with sand and mud, to cover the vegetable beds with earthy strata. It is further deserving notice, that over a large part of the plain of the Mississippi, the rapid annual growth of grasses and thistles, exceeds any thing of which this part of Europe affords an example; this enormous mass of vegetation perishes every winter.

Though the vegetation of the ancient coal fields, belonged to different families from those that flourish in the plain of the Mississippi, yet their chemical composition was similar, and there cannot be a doubt, that the present vegetation of the Mississippi plains might form mineral coal, if subjected to the same processes, that have changed the vegetation of our coal fields into coal.

Coal fields in the Valley of the Ohio.

A very interesting article on the coal fields in the great valley of the Ohio, by Dr. S. P. Hildreth, is given in Professor Silliman's American Journal of Science and Arts, for October, 1835, from which the following account is extracted:—

"The mineral district described by Dr. Hildreth, spreads over a space of four or five degrees of latitude, and as many of longitude, through which the river Ohio winds, receiving in its course numerous tributary and navigable rivers. The district extends northward beyond Pittsburgh, and southward to the 37° of latitude. This region may be called the southeast termination of that immense valley which lies between the Rocky mountains on the west, and the Alleghany range on the east; a vast tract of country without mountains, but gradually declining towards the mouth of the Mississippi. The soil in the valley of the Ohio is in general a deep and productive alluvial one, yielding an abundant supply to its rapidly increasing population, and promising an adequate support for the numerous millions that in a few generations will probably occupy this region.

"The first of its mineral treasures, coal, is most important to a country dependent on steam navigation for its prosperity; it occurs in an exhaustless quantity, and is in general of an excellent quality, being bituminous or coaking coal, well suited for the smelting of iron ore: indeed some of the beds are so pure, that the coal may be used without coaking in the iron furnaces. The average thickness of the principal beds of coal is from four to six feet; in some situations they are ten feet or more: the beds are free from the dislocations and faults which so much impede the operations of the mines in other coal districts. The great peculiarity of the structure of the coal strata in this region is, that they are in general nearly horizontal, having only sufficient inclination to drain off the water; many of the beds are situated above the level of the rivers, and may be traced round the sides of the hills, at the same elevation, or nearly so, on each side. This circumstance gives an amazing advantage in working the mines, as no perpendicular shafts are necessary to reach the coal, but passages can be cut through it from one side of the hill to the other; and the expense of lifting the coal from the depth of seven and eight hundred feet, as is most frequently required in the best English coal mines, is altogether avoided. Beside this advantage, the proprietors can ascertain accurately, without boring, and with scarcely any expense, the exact thickness of each bed of coal, before they commence mining operations.

"The largest of the lateral rivers that pour into the Ohio, in this region, are the Muskingum and the Scioto, on the western side of the Ohio, and the Alleghany river, the Monongahela, and the great Kenawha, and little Kenawha, on the eastern side; each of these rivers give their names to the extensive lateral valleys through which they flow. These valleys, as well as many minor ones not here enumerated, contain coal fields, differing in the number and thickness of the beds, but for the most part similar in structure. If we take part of the valley of the Monongahela, between Morgan Town and Pittsburg, from Dr. Hildreth's memoir, it may serve as a type of the coal fields in the other valleys. The strata that accompany coal are chiefly sandstones and argillaceous shale. 'No less than four deposits of coal are found from the tops of the hills to the bed of the river. The uppermost bed of coal lies at an elevation of three hundred feet, and is six feet in thickness; the second is one hundred and fifty feet above the river, is seven feet in thickness, and the coal of an excellent quality. The third bed is only thirty feet above the river. The coal is rather of an inferior quality, and only three feet in thickness. The fourth is a few feet beneath the bed of the river, in one part of the valley,

but some miles above it, it appears in the bed of the river, and continues to do so for fifteen or twenty miles. It is six feet in thickness. This coal is of a superior quality, highly bituminous, and free from sulphur, or sulphuret of iron, and in repute for smith-work. There are in all the beds twenty two feet of coal. At the bottom of the best coal beds is found a deposit of about eighteen or twenty inches of coal of great purity, and which, for the manufacture of iron, is fully equal to charcoal, burning without leaving any cinders, and very little ashes.' In other parts of this valley there are only three beds of coal, all situated above the level of the Monongahela river. When we consider the facility with which the coal of this region can be obtained, and its almost exhaustless supply, it may, perhaps, be regarded as containing the most valuable coal fields at present known in any part of the world. It is a remarkable circumstance that all the coal of this region is bituminous, whilst the coal in the eastern states is nearly all dry or hard coal, burning without smoke, called by mineralogists *anthracite*.

"The iron ore occurs in various forms, but the extent and thickness of the beds have not yet been fully traced. Several furnaces have been already worked, which at present produce about thirty thousand tons of pig iron annually."

E.

ON THE NEW NOMENCLATURE OF THE TERTIARY STRATA.

A NEW nomenclature of the tertiary strata has been lately proposed, which is based on the numerical proportion of recent to ancient fossil shells, as given by M. Deshayes. (See p. 285.) By recent shells is to be understood those analogous to existing species. The divisions are called *Eocene, Miocene, Pliocene,* and newer *Pliocene.* The numerical proportion is stated to increase in each by a certain per centage, beginning with the Eocene, from the Greek *Eos,* or Aurora, indicating the first dawn or appearance of recent species. The nomenclature of a science is the common property of all its cultivators, and should not be invaded or changed, without some obvious advantage is to be thereby obtained. If the nomenclature be a scientific one, it ought to be based upon characters or properties fully admitted and established. The numerical proportion of ancient and recent shells, in each tertiary division, it must be exceedingly difficult, if not impossible to determine, because we know not the limits of variation which may take place in shells, by difference of age, or the different circumstances in which the animals may be placed. These variations, I have stated, are much greater in some instances, than the difference of form in shells, supposed by many conchologists to belong to distinct species. The proposer of the new nomenclature admits, that when the geologist has made a collection of shells from a tertiary formation, he cannot be expected to discover the proportion of recent to fossil shells; he is told that he must consult some able conchologist, who is to determine the proportions for him. Now this method has been tried, with respect to the shells of the Crag, and other tertiary formations, and has been found entirely fallacious. Different conchologists have given very different and opposite enumerations of the proportions. Where M. Deshayes finds in the Crag fifty per cent. of species analagous to recent shells, other eminent conchologists say there are none. This discrepancy ever must arise from a method so vague and empirical, depending upon the skill or caprice of the different shell sorters. If English geologists resolve to adopt the new nomenclature, it will be necessary to elect some one conchologist as *Imperator Cochlearum,* to wear the triple Eocene, Miocene, and Pliocene crown, from whose decision there shall be no appeal. M. Desnoyers has published some excellent observations on the difficulty of determining the relative age of tertiary formations, by the law of proportional numbers of fossil species, analagous to existing species.—*Bulletin de la Soc. Geol. de France, Avril,* 1837. This article is translated, and given, with additional observations, in the Magazine of Natural History, March, 1838, now ably conducted by Mr. Charlsworth. Its perusal must, I think, convince every unprejudiced reader, that the per centage system of classification cannot form the satisfactory basis of a scientific nomenclature.

Great caution is indeed required in drawing inferences from fossil conchology alone, when unsupported by the evidence of position (see p. 283,)

or by collateral testimony. For want of this caution, the most extravagant opinions have been advanced. A foreign naturalist, disregarding the remains of the elephant, the rhinoceros, and the hippopotamus, that occur abundantly in the Crag of Norfolk, and in the strata over it, and drawing his conclusions from the shells alone, asserts, that the temperature of England at the epoch of the Crag, was that of the arctic regions. But the above animals, particularly the rhinoceros and the hippopotamus, are constant inhabitants of warm climates, and wherever their remains occur in northern latitudes, it is considered as a proof of the high former temperature of such latitudes. To reject the evidence afforded by terrestrial animals, whose habits are well known, and to adopt an opinion directly opposed to it, from the shells of marine animals, of whose habits we know nothing whatever, is like rejecting the advantage of clear daylight, when crossing an unknown country, and preferring to explore the path at night, by the feeble glimmering of a glow-worm.

GLOSSARY.

Some fossils are named in the present volume without any explanation; it has, therefore, been thought desirable for the benefit of the geological student, to annex a glossary, stating the division or class of animals to which they belong.

The letters P. O. imply that there is a description in the Preliminary Observations; M. L. and T. L. stand for Mountain or Transition Limestone; L. Lias; Oo. Oolite; G. s. Green sand; Ch. Chalk; Tr. Transition; Sec. Secondary; Ter. Tertiary; Rec. Recent; Fos. Fossil.

Alcyonites, fossil alcyonia. Zoophytes nearly allied to sponges, the production or habitation of polypi. Rec. and Fos.

Ammonite. See P. O. Sec.

Ananchytes, a helmet-shaped echinus. Fos. Ch.

Anomia, a bivalve with one valve perforated.

Baculite. See P. O. Fos.

Belemnite. See P. O. Fos. Sec.

Buccinum. See P. O. Rec. and Fos.

Caryophillia, a branched madrepore with a star at the end of each branch; each star has a mouth and tentacula. M. L. Fos.

Cerithium, a univalve turriculated shell. Ter.

Crinoidea, lily-shaped encrinites.

Dudley fossil, trilobite. Plate V. Tr.

Echinite fossil, various species. Sec.

Echinus, sea urchin.

Encrinite. See P. O. Tr. and Sec.

Enthrochite. See P. O. M. L.

Euomphalus, univalve unchambered shell, involute, and compressed. M. L.

Fusus, a spindle-shaped univalve.

Gryphea arcuata, or gryphite, a deeply curved bivalve shell with a flat lid. L.

G. dilatata, the sides more expanded. Oo. Some species of Gryphea are still living.

Hamite. See P. O. G. s.

Helix, shells of the snail family, terrestrial and aquatic.

Hippurite. See P. O. Ch.

Ianthina. See P. O. Rec.

Inoceramus, a bivalve with an oblique beak. Ch.

Lily encrinite. See p. 196.

Lymnea, a fresh water univalve, Rec. and Fos.: the shells sometimes called Lymnites. Ter.

Madrepores, stony polypi, with concentric lamellæ, resembling stars. In a living state, the stony matter is covered with a skin of living gelatinous matter, fringed with little bunches of tentacula; these are the polypi; the skin and the polypi contract on the slightest touch.—*Cuvier*. Madrepores are sometimes united and sometimes detached: where the laminæ take a serpentine direction, they are called

Meandrina, or brain stone.

Nautilus. See P. O. Rec. and Fos.

Nummulite. See P. O. Fos. Ter.

Orthoceratite. See P. O.

Paludina, a fresh water univalve, nearly resembling the shell of a snail. Wealden.

Patella, the limpet shell. Rec. and Fos.

Pectunculus, an orbicular bivalve. Sec. and Ter.

Planorbis, a discoidal univalve fresh water shell, nearly resembling an ammonite, but without chambers. Ter.

Productus, a semi-globular bivalve, the lid nearly flat. M. L.

Scaphite. See P. O. G. s.

Septaria, stones divided into cells or partitions, common in argillaceous strata; sometimes the cells are empty.

Spatangus, a species of fossil echinus. Ch.

Spirula. See P. O.

Sponges, living and fossil. The flints in chalk are frequently silicified remains of sponges.

Terebratula, a bivalve with an advanced and curved beak, which is perforated. Numerous species. Rec. and Fos.

Trilobite, a crustaceous fossil animal. See Plate V. T. L.

Turrilite. See P. O. G. s.

Vegetable fossils. See Chap. II.

ADDENDA.

At the conclusion of Chap. XXIII, I fully intended to have noticed the ingenious theory of Professor Babbage, which ascribes the local elevation and subsidence of the surface of the earth to the expansion or contraction of rocks or strata, caused by an increase or decrease of temperature, either from the effect of internal heat, or external radiation of heat. That rocks, as well as metallic substances, are expanded or contracted by variation of temperature cannot be denied, and the long continued action of heat on certain portions of the earth's surface may, in some instances, occasion elevations or depressions sufficient to raise or depress the land gradually several feet above or below the level of the sea. In this way the changes of level that appear to be slowly taking place on the coast of Greenland, Norway, and Sweden, may, perhaps, be satisfactorily explained. We know, however, that explosive or volcanic forces are in frequent operation, sufficiently powerful to shake or upheave suddenly an immense extent of the surface of the globe, and it is difficult to believe that lofty mountain ranges, or entire continents, can have been raised by the gradual expansion occasioned by variation of temperature; the latter cause may be compared to the slow insinuation of a wedge, the former to the explosion of a mine. The effects of explosive forces can be distinctly traced in every quarter of the globe; those of gradual expansion or contraction, from variation of temperature, cannot admit of direct proof. Professor Babbage applies his theory to explain the subsidence or elevation of different parts of the coast of Italy, and particularly to the temple of Serapis, near Puzzuoli. Three remaining columns of this temple present satisfactory evidence of their having been submerged to a certain depth below the level of the sea, where they remained for a considerable time, and were subsequently raised to their present elevation. The temple is situated in the midst of a volcanic district, and near to Monte Nuovo, a volcanic mountain elevated in a few hours to the height of 450 feet, in 1538; at the same time, the country around was permanently elevated some feet above its former level. See p. 334. Here we have a cause of elevation in frequent activity adequate to the effect, and the geologist is not required to seek for any other, unless it be to explain the present nearly erect position of the three columns; but nothing is more common during violent earthquakes, than for certain parts of a large edifice to remain uninjured, when all the surrounding buildings are reduced to ruins. An account of the columns of the temple near Puzzuoli, and the evidence they present of subsidence and elevation, was first published in a report of the National Institute of France for 1810. The columns, which are 42 feet in height, are each carved from a solid block of marble; about twelve feet from the base they are perforated all round by a marine bivalve shell, *modiolus lithodomus*, common in the Mediterranean, the perforations begin at the same height in each column, and are continued several feet

above, but the upper parts of the columns are not perforated. It is evident that the lower part of the columns must have remained a considerable time beneath the level of the sea, during which they were pierced by the lithodomous shells. In other parts of the coast, ruins of temples may still be seen below the surface of the sea. Professor Babbage has given an account of his theory, with tables of the expansion of rocks at different degrees of temperature, in a work which he entitles a *Bridgewater Treatise.*

In a note, page 155, I stated my intention of giving a fuller explanation of the formation of narrow valleys or ravines, originally opened by fissures in mountains. I had prepared the descriptions and sections, but on reconsideration, I found the subject would occupy too much space in an introductory work. The fissure A in the cut, page 155, and the line D, may serve to explain the original formation of a narrow transversal valley, and its subsequent enlargement.

In the tabular arrangement of secondary formations, p. 191, the *white cretaceous limestone*, A, in the Wealden section, is a bed with flints, closely resembling chalk, over the Portland freestone; its thickness is perhaps too inconsiderable to entitle it to be enumerated with the principal secondary formations, and my reason for placing it there should have been given in an explanatory note. Wherever this bed crops out inland, it may, from its close resemblance to chalk, and being so called provincially, greatly perplex the geologist who visits the Weymouth district for the first time. In my memoranda I designated it, for the sake of distinction, fresh water chalk. Whether we regard this bed as the commencement of the fresh water formations, or the termination of the marine beds, it forms a remarkable boundary of separation; it has been generally classed with the Portland oolite. The Petworth limestone, b, has by an oversight been placed with the Purbeck beds; they are both fresh water limestones, but the Petworth is subordinate to the Weald clay, as stated, pages 231, 233.

APPENDIX

TO THE

THIRD AMERICAN FROM THE FIFTH ENGLISH EDITION OF

BAKEWELL'S GEOLOGY.

SUGGESTIONS RELATIVE TO THE

PHILOSOPHY OF GEOLOGY

AS DEDUCED FROM THE FACTS AND TO THE CONSISTENCY OF BOTH THE FACTS AND THEORY OF THIS SCIENCE WITH

SACRED HISTORY.

INTRODUCTORY REMARKS.

MY acquaintance with the Geology of Mr. Bakewell commenced with the first edition, published in 1815.

Being strongly impressed by its perspicuity, attractiveness, and sound philosophy, I made it the companion of my lectures on this science, and in 1829, an American edition, from the third English, was published at New Haven, under my supervision, and with the author's privity and approbation. The work met so favorable a reception in this country, that a second American edition, from the author's fourth, also with his approval, was edited by me in 1833, and thus it became generally known in the United States, as a book of standard authority.

It appears, that the republications in this country produced so favorable an influence at home, that, from being less generally known there, than its great merits deserved, this work soon made its way into several of the first British universities; and we infer, from the appearance of a fifth edition, that it continues to main-

tain its ground with other excellent treatises on geology, which have appeared long since this was first published.*

It is in accordance with Mr. Bakewell's wishes, that I now pass a third American edition to my countrymen, not doubting that I am doing to them and to all our students of geology an acceptable service.

In relation to the present edition, I have revised the discourses which were appended to the two former American editions of 1829 and 1833. They have been greatly condensed, and to some extent written anew, with the intention of bringing them up to the present state of the science.

The outline of my lectures, annexed to the first American edition of 1829, does not present a correct view of the courses which I now give. Fifteen years have elapsed since that outline was first sketched, and ten since it was published. Within those periods geology has made great advances, particularly in the proofs of igneous action, in all ages, ancient and modern; and perhaps my own admissions of its agency were not commensurate with the proofs that existed in 1833. The powerful direction early given to my mind, towards the Wernerian theory, by the captivating eloquence of the late Dr. John Murray of Edinburgh, whose lectures on geology as well as chemistry I attended, was not, at that time, fully appreciated by myself.

I was also a deeply interested listener to the lectures of Dr. Hope,† based on the Huttonian theory, and I was a careful student of Playfair's splendid illustrations of that theory; while Playfair himself, with many other eminent men of that school of geology, as well as of its rival,‡ was then in full vigor and activity at Edinburgh. It was delightful to listen to their eloquent statements and acute reasonings. In this way I heard both sides of the question fully vindicated, while, from my youth and inexperience, I endeavored to sustain a neutral position, and reserved the liberty to decide ultimately, with an unbiased mind. Still I was, to a degree, incredulous in regard to the fundamental postulates of

* We are informed that it has been translated and published in Germany.

† The distinguished Professor of Chemistry, &c. in the University of Edinb.

‡ Professor Jameson, then recently returned from Germany, where he had studied under Werner, had not at that time entered on his public duties.

the Huttonian geologists, and could not perceive that they made out their case, as to the extent and energy of internal fire. The powerful arguments in favor of great igneous action, contained in Mr. Bakewell's Geology, were supported by Dr. Daubeny's fine Treatise on Volcanoes, and this by the full and exact work of Mr. Scrope on the same subject, with particular reference to the extinct volcanoes of France, illustrated also by an ample atlas of volcanic regions. The more recent exhibition of proofs by Mr. Lyell, as to the extent, persistence, and energy of igneous action; the satisfactory evidence accumulating every year respecting the increasing internal heat as we descend into the earth; the decisive influence of galvanic power in mineral veins, as ascertained by Mr. Fox, its efficiency in producing mineral crystallization and its power even in rousing into life the long latent eggs and germs of insects, as established by Mr. Crosse—with the splendid proofs which our galvanic and electro-magnetic machines now afford of an igneous energy inherent in the earth—an energy which knows no limits—attended also by magnetic and decomposing power, equivalent to all which geology demands; these and many other considerations that might be stated, have removed my doubts, and I have been for a series of years in a condition to do full justice to the internal agency of fire, as my various classes in the university and elsewhere can attest.

It is of little importance to occupy the reader's attention, even for a moment, with my own personal views and opinions, nor would I have ventured to do so, were it not of some importance that the science may not suffer by any apparent, although not real, caprice of opinion in those who teach it to others. I have therefore thought it but honest to make this frank declaration, my *amende honorable*, of the change in my views, and of the grounds of it; and perhaps it may not be entirely without utility, as an exhibition of the effect of progressive development and accumulation of evidence upon one mind, inasmuch as other minds may, by similar means, be led to the same result. If, however, I still sustain the claims of water and of all things which, by the aid of heat and pressure, water is able to dissolve—to more efficiency than is now generally conceded to them—it is I trust not so much because I am still tenacious of early impressions, as because

the state of experimental science, both mechanical and chemical, fully bears us out, in attributing powerful solvent properties to water, aided especially by heat and pressure and many active chemical agents.

The remarks on the consistency of the facts and theory of geology with the scripture history, although superfluous with respect to learned geologists, and even learned theologians, who have studied and understood both sides of the question, appear to me to be still demanded by the state of moral feeling, and by the imperfect comprehension of geological truths on the part of the majority even of our educated people. I have therefore retained a condensed view of this question, which was discussed in connexion with the edition of 1833.

I. General Object of Geology.—The object of this science is to ascertain the structure of the earth; the nature of its mineral aggregates; their disposition and arrangement, forming rocks and mountains; the relative position and nature of the rocks themselves, with their included minerals and organic remains; the useful substances which they contain; the natural associations of these with other substances; the proximate causes, which have given the mineral masses their present form and position; and those, which, operating upon them still, are causing them to undergo alterations, more or less considerable, and are producing changes, which will ultimately give them new forms of existence.

II. Positive and Speculative Geology.—It is obvious, therefore, that geology is erected upon observation, and not upon mere speculation; yet, speculation is with propriety admitted, as an important means of advancing the science; but it is of no value if not founded upon facts, and they must never be contradicted by it.

Positive is therefore the parent of speculative geology, and it proceeds, like the other natural sciences, upon a careful examination of particulars; from particular it ascends to general conclusions, and upon these builds legitimate theory. Thus, there is a clear distinction between geological theory and geological hypothesis. The former draws conclusions directly from facts, and follows strictly the inductive course. It has therefore the same

foundation, as general physics; and its conclusions often approximate to demonstration. The latter also appeals to facts, but in a manner less conclusive, and it sometimes makes suppositions of facts, not actually proved to exist.

III. Former and present State of Geological Knowledge in this Country.—Before the American revolution, geology as a science, had no existence in this country, and indeed there was hardly any thing in Europe that deserved the name.

In Mr. Lyell's Principles of Geology, there is an interesting historical sketch of the rise and progress of geological research and opinion, from the ages of Grecian, Arabian, and Roman philosophy to that of the revival of letters in Europe; and from that period, through several centuries to our own time. Vigorous minds have indeed appeared in various and remote periods, which have formed just conceptions of some parts of geology, but it could not be said to have taken the form of a science until the Wernerian and Huttonian schools began their friendly conflicts, about 60 or 70 years ago.

In this country, considerable attention was early bestowed upon the research for metals and other valuable minerals, as is evinced by numerous excavations in our hills and mountains, whose date is generally in the first half of the late century. Several of the men are still living who led the way in introducing scientific geology among us. William Maclure* was the man who, from extensive personal examination, made the first geological sketch of the United States, after having visited geologically, most of the countries of Europe; he has also given us much interesting geological information respecting the West Indies, Spain, and other countries. He and others, his juniors in years and in the date of their knowledge, can well remember, when the names of the most common minerals and rocks were scarcely known in the United States. Now, there are geological cabinets and schools in many places, and many geological surveys have been made, or are in progress, under public authority. We have numerous good reports on states and territories, and many valuable

* Who now, at an advanced age, resides in the city of Mexico—a country which he finds congenial to his health.

memoirs on particular districts; they are to be found also in scientific journals, in books of travels, especially of the exploring expeditions sent out by the American government; in the transactions of learned societies; in detached publications, and sometimes even in the newspapers. These materials are of great value; but much more must be done before they will be sufficiently copious to enable some master spirit to reduce the whole subject to order, and thus to give a full and digested account of American geology. Foreign geologists will do us the justice to remember, that our field is vast, while our laborers, although every year increasing in number, are still comparatively few, and they are, generally, men occupied by other pursuits; this country is rarely explored by those whom fortune leaves at ease to follow a favorite object. The learned leisure of Europe, and especially of England, is here almost unknown, and our most efficient cultivators of science are also laborers in other fields. But the habit of making efforts by systematic industry, is often an equivalent for leisure. Many of our geologists labor with zeal and effect, and in the scientific corps, now surveying several of our states, we have men who are able to maintain their standing with those of any country.

IV. Limits of our Knowledge of the Earth.—It is only the *crust*, the superficial part of our earth, that we can examine; a few miles or leagues in depth of its outer rind. We no longer attempt, by a brilliant excursion of the imagination, to account for its present form; poetry and fiction have ceased to perform the work of philosophy; those obsolete hypotheses, falsely called theories—many of them adorned by the eloquence of powerful minds—which substituted waking dreams for the patient examination of facts, are no longer regarded, except as monuments of the restless activity of the human mind; which is inclined to repose on almost any conjecture, however visionary, rather than to confess its weakness and ignorance.*

In Europe, and we are now happy to say in America also, a great number of highly qualified men are occupied in geolo-

* The geological student may find a spirited outline of the most prominent geological hypotheses in Cuvier's Introduction to Geology; they may be read as a matter of amusement; but it will be easily perceived, that they bear no closer analogy to modern geology, than the visions of Alchemy sustain to modern chemistry.

gical researches; collectively they bring to the investigation, all requisite science and the habit of careful observation and induction, with the industry and patience, which are demanded. The progress made in these inquiries, even since the commencement of this century, is wonderful. Districts, provinces, and countries are surveyed; and this kind of research, favored by the propensity for travelling, to which it affords both a strong incitement and a high gratification and reward, will, doubtless, continue to be extended, until there shall be no countries unexplored, except those from which the *scientific* traveller is debarred, by insuperable moral or physical impediments.

Geology takes rank among the physical sciences, and is worthy of the attention of the greatest minds.

In grandeur, it falls indeed short of astronomy; and what physical science does not; since, astronomy presents to our optics, or to our intellectual vision, the "great frame work" of the universe; we pass from the view of our own planet to the entire planetary system, of which our earth is a member; and from this system, to other and similar systems; and to the immense systems of suns innumerable, with their attendant worlds, arranged and connected, in perfect harmony; performing all their revolutions without interference, or irregularity, and illustrating the power and wisdom and sustaining energy, of the omnipotent Creator and Governor. Still the structure of a single planet is a subject of great interest and grandeur; especially as we may reason from it *analogically*, respecting the structure of other planets.

V. Modes of Investigation and Sources of our Knowledge.—Our direct penetration into the earth, by mines, the deepest excavations of art, has scarcely exceeded three thousand feet—a little more than half a mile, not $\frac{1}{8000}$ part of the earth's diameter or $\frac{1}{4000}$ part of its radius.

It might therefore at first view, seem that we can attain only a very slight knowledge of the internal structure of the planet, and that it would be idle to attempt to speculate respecting that of which we can see so little. Still, we are able to reason correctly on this subject, for we have many sources of information and ample means of perusing the internal structure of our globe.

1. *The obliquity of the Strata.*—The strata or natural beds of rocks are found in all positions, from the perfectly vertical, to the perfectly horizontal. Were they all horizontal, it is obvious, that the edges could come into view, only on the sides of mountains, in the banks of rivers, on promontories, or in artificial excavations; and that, in a tolerably level country, we might travel over many leagues, and see very little change in the rock formations.

But if the strata are inclined to the horizon, then, their edges must come into view, unless the rocks are concealed by the soil or by ruins. Thus the strata, that in a given situation are many miles below the surface, may emerge, and *crop out*, in some other place. Were the soil and diluvium removed, from a series of inclined strata, then, their edges would appear, and we could have no reasonable doubt that we should see an adequate representation of the subterranean geography, as far as those strata extended downwards; perhaps for many leagues—or possibly for hundreds of miles beneath the surface. The same instruction is obtained from vertical strata, and indeed from those in all positions, except the perfectly flat; and even then, we are not without means of information.

2. *Horizontality—Density of the Earth.*—Strictly, a horizontal position is parallel to the general curve of the earth's surface, considered without reference to the hills and mountains. Were this horizontal position strictly preserved, and were there no perforations and ruptures of the strata, by artificial or natural causes, we should, except in the sides of hills and mountains, see only the upper stratum of rock, and our knowledge of the geology of the region in question, would be confined, very nearly, to the visible material beneath our feet. A horizontal stratum may overlie parallel strata, descending so deep as to come out obliquely at points distant from the position of the observer, and thus to exhibit inclined or even vertical strata cutting off a segment of the globe.

In common with the pressure of superincumbent masses, it may be proper to mention the density of the earth. By the conclusions of the British and French philosophers, the mean specific gravity of the earth is at least twice that of the most common rocks and stones.

This important conclusion implies nothing more than a highly condensed state in the materials in the interior of the earth; still it does not prove a prevalence of metals, in the sense in which they are generally known to mankind. It is, however in full proof, that metals, such as are known only to chemists, form the basis of the rocks, and in their oxidized and mineralized condition, they may, from pressure or from other causes, acquire a high specific gravity. This is illustrated by carbon as it exists in diamond, in which it is three or four times as heavy as in the bitumens, and six or eight times as heavy as in charcoal; alumina, in sapphire, sustains a similar relation to the alumina of clays, and so does pulverulent carbonate of magnesia to that earth in boracite or in chrysoprase; or silica in swimming fluid *(quartz nectique)* to the same substance in rock crystal. Thus the specific gravity of the entire mass of the earth compared with that of the surface may present no contradiction or inconsistency.

3. *Mines and Wells.*—The excavations in mining are the most profound that have been made by art. The deepest mine in the world, that of Truttenberg in Bohemia, penetrates three thousand feet into the earth. In all mines, the strata being perforated and broken, we obtain the most satisfactory information, as to the nature and arrangement of the rocks. Few of the mines of England are, in perpendicular descent, deeper than a quarter of a mile, (Dolgoath in Cornwall,) and none in the United States exceed four or five hundred feet, (Richmond coal mines, and those of Pennsylvania.)

The evidence afforded by wells is of the same nature. The depth attained rarely equals one hundred feet, but in some instances it extends to two hundred, three hundred, four hundred, &c. as at Carisbrooke Castle in the Isle of Wight, on the plain or valley of London, &c. (Conybeare and Philips.)

4. *Boring for Salt Water, Salt Mines, Coal, &c.*—This affords similar, though less distinct evidence; because the materials are brought up, in the state of powder, or at least of small fragments, and a very imperfect idea is thus obtained of their original appearance; sufficient however to enable us to decide on their nature. These operations are often carried on to the depth of several hundred feet—sometimes 600 to 800 feet or more.

5. *Roads, Canals, and Tunnels.*—Roads and canals are sometimes cut through diluvium, as on the Welland Canal, in Upper Canada, where the cut is in some places, more than fifty feet deep, in a stiff tenacious clay; and even through solid rocks, as at Lockport on the Erie Canal, where for two miles or more, a very solid, subcrystalline limestone has been excavated by blasting, in many places to the depth of thirty feet, disclosing not only the nature of the rock, but many beautiful imbedded minerals and fossils—strontian, gypsum, calc spar, corals, crinoidea, &c.

Tunnels are less numerous, but every one has heard of that of the Duke of Bridgewater, between Liverpool and Manchester, and of the Thames Tunnel, below London, intended to serve as a substitute for a bridge. That under Standedge, between Huddersfield and Manchester, extends upward of three miles, and is two hundred and twenty yards below the surface.

It appears that they were not unknown to the ancients. From the Stadium near Athens, situated in a natural defile, the vanquished charioteers retired through a tunnel which perforated a neighboring hill, and thus those who had failed of victory were screened from the sneers and insults of the populace.* Tunnels are becoming common in this country, as between Philadelphia and Pittsburgh; at Harlem, near New York; at Norwich, Connecticut, and in various other places. These and all other excavations into the earth add to our means of geological information.

6. *Rivers and other Water Courses.*—Brooks gently transport gravel and sand, and rivers rush through mountain defiles, as if they had burst the rocky barriers, transporting not only sand and gravel and pebbles, but at times large bowlder stones, bearing them along and vexing them with incessant friction, till their angles are rounded or obliterated. The rivers have sometimes flowed at a higher level, or their waters are the remnants of lakes whose barriers time has broken or worn away; and water-worn ledges are often found at elevations higher than where the floods can now flow. This is seen two or three miles below Bellows' Falls, on Connecticut River, where the primitive rocks

* Dr. Howe's personal communications, Aug. 11, 1828.

shew the same water-rounded angles, furrowed lines, and even pot holes, formed and polished by ceaseless attrition, as are seen at the Falls themselves, whose torrents are now incessantly wearing the rocks. Similar facts are observable at the head of Lake George, fifty feet and more above the lake, in ledges of transition limestone, over which no water now flows. The same appearances are seen at the great falls of the Potomac; where, for a long distance, and at a considerable elevation above the present bed of the river, the angles are rounded and smoothed, and there are numerous holes in the rock, either shallow and irregular, or deep and cylindrical, like those of cataracts, and certainly produced by the same causes, the wearing of water, aided by whirling stones.*

The passage of the Shenandoah through the Blue Ridge—of the Connecticut at Middletown, through the Haddam hills, and of the rivers in the Rocky mountains through their defiles; these are a few among innumerable examples of this kind. The rivers have rarely burst their barriers; in general, they have merely uncovered the rocks so that their characters can be observed; they have not generally formed their own beds, but have deepened and altered their channels. The Genesee and Niagara rivers, whose banks are often precipitous and several hundred feet high, give sections of the strata wonderfully distinct and beautiful. Thus the wearing power of water contributes to the mass of geological evidence.

7. *Valleys and Defiles, Banks, Precipices, Cliffs and Promontories.*—In every mountainous country not covered with soil and ruins, these natural sections being often deep, abrupt, and of great extent, expose the stratification on the sides of the hills and mountains, and thus the structure is revealed. As a large part of the earth is mountainous, provision is thus made, on a great scale, for judging of the interior of the planet. The shores of the seas and of the great lakes, and all elevated countries, abound with such exhibitions. Many of them are indeed inaccessible except in boats, but however viewed, they exhibit the stratification and structure more or less distinctly.

---

* American Journal, Vol. IV, p. 44.

8. *Landslips, Slides and Avulsions.*—The peaceful dweller in the beautiful Isle of Wight, in the English channel, not unfrequently sees the high chalky cliffs of that coast, that have been undermined by the sea, totter to their fall, till they come thundering down in piles of ruins; and even at some distance inland, away from the sea, they occasionally slide or slip from their seats, overwhelming the plains below.

The Alpine mountaineers witness still more stupendous catastrophes. Large portions of mountains are precipitated with frightful devastation upon the valleys and plains, filling the bosom of lakes, spreading desolation far and wide, and burying villages in the wreck, or sweeping them away by the sudden rush of the waters.

The mountains of Vermont and of New Hampshire, have been the scenes of similar catastrophes, and the Notch in the White Mountains of the latter State, will long record the desolations of 1826. The Notch is a grand defile in these mountains, five or six miles in length, formed by a double barrier, rising abruptly half a mile or more in perpendicular altitude, from both sides of the wild roaring river Saco, which washes the feet of the barriers. A single carriage can hardly pass between the stream and the mountains, and the road is in some places cut into the mountain itself. The ridges are capped by castellated turrets of rocks, rising in high zigzag turns, which thus imprison the observer in a vast, gloomy gulf.

The sides are deeply scarred by many floods, and especially by the memorable deluge of the night of August 28th, 1826, which destroyed, in a moment, an entire family of nine, and left not one to tell their story. The Willeys occupied a lonely house in the wildest part of the Notch, at the foot of the mountains; it was a resting place for travellers. For two seasons before, the mountains had been very dry, and on the morning of August 28th, it commenced raining very hard, with strong tempestuous wind; the storm lasted through that day and the succeeding night, and when it ceased, the road was found obstructed by innumerable avalanches of mountain ruins, which rendered it impossible to pass, except on foot. They were rather slides than ruptures of the rock: they began at or near the mountain top, and bore down

the precipitous sides, the shrubs, the forests, the soil, stones and rocks; and of the latter, many of great size.

One of the torrents descended behind the house, and dividing into two branches, bore away the unhappy family, who, in the deep darkness and wild fury of the tempest, issued from their dwelling only to be overwhelmed by the torrent, which desolated the mountain gorge for a distance of two miles,* filling it with almost continued masses of ruins, borne down by the deluge from both sides of the defile.

Such are some of the disclosures made by violent torrents, by slides and revulsions.

9. *Revelations by Fire.*—Volcanic eruptions throw up into daylight the foundations of the fathomless deep below, in the form of ejected masses, or in rivers of ignited and fluid rocks, which congeal on the surface of the ground, either inflated, like the scoriæ of furnaces, or in solid forms, with no visible impress of heat. They often contain very perfect and beautiful minerals, conceived in the volcano, or dislodged from still earlier beds, from a more profound igneous abyss, from which they are urged along by the irresistible current that often ruptures the crust of the earth, and covers it with a fiery deluge. In addition to the products of actual volcanoes, we observe the ignigenous rocks, crystallized or deposited from fusion, both in the earliest and in many of the more modern epochs, injected among, and cutting across strata of almost all descriptions and ages, and thus assimilated to known products of internal fire; these proper rocky masses, the granites, the sienites, the porphyries, the serpentines and the traps, give authentic information of the unapproachable gulf of fire whence they were projected.

10. *By Cold and Hot Springs and Gases.*—The internal waters that gush cool from the fountains on land or under the

* During a visit to this place in May, 1828, two years after the event, there was still visible a vast rampart of earth, stones, rocks, and trees piled up behind the house, at the place where the torrent divided, and left the building unharmed, although it swept away the barn and cattle, sparing, however, a flock of sheep which lay near by upon a green sward. I was there again in August, 1837, nine years after my former visit, and found the ruins near the house so covered with earth, and even grass, that they were almost concealed from the eye, thus serving as a geological chronometer.

sea, or those that spout in boiling geysers from the deep caverns where their imprisoned vapors accumulate explosive force; all these bring to the surface the materials of the interior, and conspire with tornadoes of gas bursting from volcanoes and other vents, to reveal the deep secrets of the earth.

VI. Fruits or Results of the Observations made on the Structure of the Crust of the Earth.—*The earth is not*, as ignorant persons usually suppose, *a mere rude and unarranged heap of rocks* and minerals, grouped together without order or plan, and incapable of being rationally investigated.

Order, so conspicuous in the mechanism of our planetary world and the stellary universe; in the equilibrium of projection and gravitation; of cohesion and expansion and chemical affinity, and in the structure and exact economy of animals and vegetables, pervades, indeed, all the works of creation; nor is it less capable of demonstration, although the proof is less obvious, in this unconscious earth, than in the other departments of God's universal dominion.

VII. Beauty and Interest of Geology as a Science.—In relation to the beauty and interest of geology, we may remark, that no field of science presents more gratifying, astonishing, and (but for the evidence) incredible results. Man has been but a few thousand years a tenant of this world; nothing which we discover in the structure of the earth, would lead us to infer that he existed at a period more remote than that assigned to him by the Scriptures. Had he been cotemporary with the animals and plants of early geological periods, we should have found his remains, and his works, entombed along with them.

Opinion of Berkeley.—This argument forcibly impressed the mind of Bishop Berkeley, a century ago, and the following beautiful passage is cited from him by Mr. Lyell.* "To any one who considers that on digging into the earth, such quantities of shells, and in some places, bones and horns of animals, are found sound and entire, after having lain there, in all probability, some thousands of years; it would seem probable that gems, medals, and implements in metal or stone, might have lasted entire, bu-

* Principles, 5th edition, Vol. III, p. 255.

ried under ground forty or fifty years, if the world had been so old. How comes it then, to pass, that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglios, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demigods, for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during which time, we will suppose that plagues, famines, wars, and *earthquakes*, shall have made great havoc in the world, is it not highly probable, that at the end of such a period, pillars, vases, and statues, now in being, of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration,) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls, and the foundations of buildings, show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times."* This remarkable passage proves that the great man from whom it fell, saw the geological argument in a true light, and felt its force to such a degree as to convince him of the great antiquity of the earth, which he justly viewed as in no way inconsistent with the comparatively recent origin of man, or with the historical account of both events contained in the Genesis. It is easy to understand how such a mind would have been convinced, warmed, and excited even to enthusiasm, by the discoveries that have burst upon us during the last fifty years.

VIII. Organic Remains.—As we descend from the alluvial under our feet, through the strata, the lowest of which lies upon the granite, or the early slates, we are almost never without the records of life, in ages long past, and those records are drawn both from the animal and vegetable world.

Early Animals.—The shells and forms of molluscous and testaceous animals are every where seen; their casts, and their sub-

---

* Alciphron, or the Minute Philosopher, Vol. II, pp. 84, 85. 1732.

stance, are apparently preserved in stone, but are really converted, by the substitution of mineral matter, into true fossils. Myriads on myriads of these things are found, not merely in the visible, superficial strata, but in the heart of the mountains, and at profound depths, forming an essential part of the solid frame work of the globe. The animals and plants are not accidental resemblances, but authentic specimens of organic antiquity, enclosed in the strata and mountains, as the materials, in mechanical or chemical suspension in the waters, concreted around them. It was impossible that they should be due to any sudden or accidental event; the organic beings came into life, as now—performed their parts as now, and were entombed in the forming masses, which were therefore, of more recent origin.

Fossil Fishes.—If we descend with Agassiz* from the strata of newest formation, to those that lie near, or upon the primary rocks, we are astonished and delighted to find not only that shell fishes and crustaceous and molluscous animals, of various kinds, have existed in the early ages, but that fishes, furnished with fins and vertebræ, have occupied the waters of almost all geological ages, since life began, and that among the earliest, even those that are buried beneath the coal, there were races of great size, power, and ferocity; formidable from their teeth and jaws, which had, in some species, the structure of carnivorous reptiles, and whose forked tails, with unequal flukes, enabled them quickly to turn over on their backs, before striking their prey. The fossil fishes, of particular genera and species, are characteristic of particular geological formations—they extend geographically, far and wide, to distant countries, so that certain species may, if found at all, be expected in similar rocks in Europe, in America, in Asia, and Africa, and they are of every size, from inches and fractions of an inch, to several feet. They occur either solitary, or in groups, or in fragments, or in immense shoals, like those of Mount Bolca, near Verona, in Italy, where there are more than one hundred species; still, not a single fish of the strata that precede the most recent tertiary, is identical in species with any now existing in the waters of the globe.

* The great writer on fossil ichthyology, of Neufchatel, Switzerland.

Fossil Vegetables.—Vegetables are found in nearly all geological ages, after the granite family, and the labors of Count Sternberg, of Adolphus Brongniart, and others, have proved that a peculiar vegetation, adapted to the temperature, the degree of moisture, and other circumstances of the earth's successive surfaces, attended the different geological epochs.

Splendid and expensive works are now in the hands of geologists, containing exact delineations of the fossil vegetables, as far as they have been ascertained. They are of all dimensions, from minute confervæ and lichens, to gigantic stems; their structure, from mere fragments and ruins, to perfect plants and trees, has been beautifully delineated, roots, trunks, branches and leaves, with the most delicate ramifications of the skeletons of the latter; in some rare cases, the more perishable organic fructification has been made out, and the fruits themselves have been identified.

Vegetation of the Coal Period.—The most exuberant ancient vegetation appears to have been that of the coal period, and its entombed treasures now supply the world with fuel, especially in countries where the forests are exhausted, or where economy of the modern vegetation, or preference for the results of the ancient, decides the choice.

Varieties of the Ancient Fossil Vegetation.—The ancient vegetation appears in many forms, as in that of lignite, of coal, and of siliceous, calcareous, and ferruginous petrifactions, still preserving the structure peculiar to different species; and this has been made still more distinct and satisfactory, by cutting thin slices of the petrified trunks, and grinding them down until they become so thin as to be transparent, when the microscope reveals the internal arrangement of pores and fibres, which characterizes the family. Thus, it has been made to appear, that coniferous trees of forest growth, preceded the coal formation in the south of Scotland and the north of England, and that Zamias, Cycadeæ and other palm-like trees preceded the chalk in the south of England. No species of the ancient world is identical with any one of the modern, and, as has been already remarked, the early vegetation implies, generally, a warm and moist climate, and great fertility of production.

Aquatic Animals—Reptiles.—Animals, almost exclusively marine, attest the great prevalence of the ocean in the earlier geological periods, and it is not until we have passed the coal in the ascending order, that we begin to find reptiles of marine, or amphibious families, and ultimately, still higher up, of terrestrial races. With a similarity of type to the reptile families of the present day, both their genera and species are, however, without a single perfect copy in modern times. Some were carnivorous, and swam in the shallow seas, estuaries, lagoons, and bays, and preyed upon fishes, molluscous animals, and each other. Some lived on land, and were herbivorous, and although a few species, the megalosaurus and iguanodon, for example, were colossal in size and terrible in form, it is probable that the latter of these terrestrial saurians was harmless and inoffensive, while the tooth of the megalosaurus would indicate a ferocious animal of prey, like the marine saurians. Bones of many genera and species of the reptile tribes, especially the saurians, have been found, and of some individuals, entire, or nearly perfect skeletons;—among them, those of vast dimensions have been discovered, enclosed in the solid rocks, along with their petrified and half-digested food, and with their exuviæ, called coprolites.

Marsupials.—If the reptiles formed the transition from the marine animals upward—the marsupials, as they are called, were the link between the ancient reptiles and terrestrial quadrupeds. The marsupials, of which the opossum is an example, receive their young (which, although born, are still immature) into an exterior pouch or abdominal sack, and there nourish them at their paps, until they are fitted to go abroad, and to encounter the vicissitudes of their peculiar modes of life. These are the only animals hitherto found below the Chalk which approximate to the proper terrestrial character. Dr. Mantell has, however, found the bones of birds in the Wealden beneath the Chalk, Dr. Buckland found them or the bones of flying reptiles in the Stonesfield slate, and Prof. Hitchcock has discovered numerous tracks of animals, believed to be those of birds, and possibly of reptiles, some of them of gigantic dimensions, in the new red sandstone of the Connecticut river.

Fossils of the Chalk and Tertiary.—The Chalk then follows, with its immense and varied marine treasures; and then the lower

tertiary, still marine, and then the middle tertiary, where proper and fully characterized terrestrial animals are first found; then, through the remaining beds of tertiary, both marine and fresh water, we find molluscous animals, fishes, reptiles, cetacea and vegetables, verging towards, and even identical with those of our own times. Occasionally we discover also terrestrial animals, but still, different from the modern, until, at last, in the diluvium, and alluvium, and the most recent sedimentary, and concretionary formations, we discern animals and plants, still more and more like those now living, and finally graduating into perfect identity with existing races.

The pages of our author will disclose the great variety and extraordinary form, and, in many cases, colossal dimensions, unrivalled at the present time, of some of the ancient animals, the megatherium, the sivatherium, the dinotherium, the mastodon, the elephant, the hippopotamus, the rhinoceros, the cavern bear, the tiger, and many others. In consequence of the most recent discoveries of geology, we are hurried from that which is stupendous and vast, to that which is inconceivably minute. The extremes of creation meet in the mineral kingdom. In the solid rocks are found both the colossal reptiles, and the microscopic infusorial animalculæ. Ehrenberg has discovered that polishing slate is made up of animalculæ so minute, that forty one thousand millions of them are required to fill a cubic inch, in every grain of which there are one hundred and eighty seven millions, and their siliceous shields are the cause of the well known effects of the tripoli, or rotten stone, in polishing steel, &c. An analogous constitution has been discovered in flint, opal, and bog iron, and the deposits of our modern peat bogs in this country, are filled with similar animalcules, the figures of some of which have been given by Prof. Bailey, in the American Journal of Science, vol. 35, p. 118.

Man no where Fossil.—Man and his works appear only in the last stages, associated with just such beings as now exist, both in the animal and vegetable world.

General Remarks.—Such is an exceedingly general and very imperfect sketch of the progressive creations of animals and plants, that have inhabited our world—have become extinct, and are, in countless myriads, entombed in the rocky strata, and in the solid

mountains. It is only on the upper surface that we discover loose and scattered ruins, either in the soil, or buried in masses of gravel, sand, and clay; ruins of rocks and fragments of strata, along with the relics of animals, trees, and smaller plants, such as we could in any reason, attribute to the catastrophe, or catastrophes of rising and rushing water, the deluges of geologists, or the deluge of the Scriptures; the latter, almost alone, being admitted to the contemplations of those who are uninstructed in our science. Now, it is matter of physical demonstration, that the earth existed for many ages before man was called into being. The whole course of geological investigation proves this view to be the only one that is consistent with the facts. To be convinced of its truth, it is only necessary to become thoroughly acquainted with the innumerable records of a progressive creation and destruction which the earth contains, inscribed on medals, more pregnant with historical truth, and more worthy of confidence, than those that have been formed by man; as much more as nature exceeds in veracity, the erring or mendacious records of the human race.

IX. Some Features in North American Geology.—Probably no country is more favored in the nature, abundance, variety, and distribution of the most important mineral treasures. The limits of these preliminary remarks must prevent even the most general summary of our geological formations, or at most, admit of nothing more than a skeleton; but the materials for information, already abundant, are yearly increasing, as may be seen in the various public reports, in the transactions of learned societies, and in the journals of science.

Of the primary and transition rocks, to which we may add the coal formation and the early secondary, we have immense ranges, extending in a northeasterly and southwesterly direction, through the continent, and comprising most of the minerals and many of the fossils that are found associated with such groups in the old world.

The Alleghanies, (including many mountains having local names,) following the general bearing of N. E. and S. W., and ranging between the Mississippi and the Atlantic, form, with their branches and connected chains, the great rain-shed of the countries east and west, and rising to two, three, four, and five thou-

sand feet and more,* give direction to the streams and rivers, either to the Mississippi, the Atlantic, or the great lakes, and the St. Lawrence.

Rocky Mountains.—In like manner, the far more stupendous chains of the Rocky Mountains, whose loftiest peaks are reported to be between three and five miles high,† give a geological character to the regions east and west, in which directions the waters flow to the Mississippi and to the Pacific, while the other contributions descend to the Gulf of Mexico, and to the Northern Ocean. It is to be regretted, that in the United States proper, there are no mountain ridges or solitary peaks, that pierce the region of perpetual cold.

Mount Washington.—Mount Washington, of the White Mountain group in New Hampshire, which approaches a mile and a quarter in height, being in 44° of north latitude, and on a continent whose average temperature is many degrees below that of Europe, throws off its snowy mantle only for a short season, in July and August, while it is clad in white, during the remaining months of the year. Even on the first day of September, (1837,) as adventurers upon this Alpine mountain,‡ we were, both on its flanks and summit, involved in a wintry tempest of congealed vapor, formed into splendid groups of feathery and branching crystals, unlike to the snows of the lower regions; the driving masses came in fitful gusts, veiling in a white cloud, all objects far and near; but occasionally breaking, admitted a flood of solar light to render visible this hoary pinnacle, and the deep gorges and valleys of the neighboring groups of mountains.

The mountains of Essex county, State of New York, between Lake Champlain and the St. Lawrence, approach the White Mountains in altitude, but no one of them is permanently snow-clad.

Mountains of Central Europe.—It is otherwise in Europe, whose grand central group of Mount Blanc, and the various

* Professor Mitchell, University of Chapel Hill, states that the Black Mountain in North Carolina, is 6476 feet above the level of the ocean. See Am. Journal, Vol. xxxv, No. 2.

† See Professor Renwick's Outlines of Geology.

‡ See Am. Journal of Science, Vol. xxxiv, p. 74.

Alpine mountains, rise far into the region of perpetual congelation; and Mount Blanc would pierce that region even at the equator. Thus is provided an eternal store-house of ice and snow, over whose wintry surface, the winds, rendered heavier by contact, glide into the valleys and plains of the countries at the feet of the mountains, and thus temper even the warm climate of Italy, preventing the extreme vicissitudes which we experience.

But these immense natural magazines have a still more important relation to the irrigation of the vicinal countries. The melting by the heat of summer, supplies copious streams to feed the innumerable rivers that flow from these grand fountains to almost every part of continental Europe, south of the Baltic. Thus, the effects of drought are in a great measure prevented, while destructive mountain floods are of rare occurrence.

From the absence of such mountains, we have no permanent stores of ice and snow, and, consequently, our rivers are liable to extreme variations of altitude and force. The Ohio, in midsummer, sometimes leaves numerous fleets aground, while occasional risings, from deluging rains, aided perhaps by the melting of the snows of vast regions, swell the river to an immense flood, that spurns the barrier of the banks, lays villages and cities under water, and expanding into an internal sea, rushes with wasting violence, over the wide-spread meadows and farms.

For this reason, hydraulic engineering is, in this country, attended with peculiar difficulties, both on account of a deficiency and an excess of water; the former rendering the works inoperative, and the latter invading or sweeping them away.

The future civilized inhabitants of the countries near the Rocky Mountains, (excepting, of course, the immense sandy deserts, which near the eastern slope emulate the sterility of Arabia and Zahara,) will enjoy advantages, in many respects, similar to those of Piedmont, Switzerland, Germany, and France, and it is easy to predict, that peculiar structures, and a peculiar state of society, will be modelled in relation to the sublime physical features of those truly Alpine regions. From this, his native land, we have too much reason to expect, that, despite of the efforts of the benevolent to avert the impending doom, the red man of the forest, not reclaimed to humanity, but abandoned to his fate, will vanish

before the prevailing arts and power, and the still more prevailin seductions of civilized life; the exterminated victim of cupidity and cruelty.

Influence of Geological Structure on Society.—It is perfectly apparent to geologists, that the scenery of a country is not more exactly stamped by its geological formations, than are the manners and employments of its inhabitants. This argument, so beautifully displayed by Dr. Buckland,* with respect to England, is capable of an equally satisfactory application to this country.

New England.—The bleak hills and long winters of New England are unfavorable to the most extensive and profitable agricultural pursuits, while the extensive and deeply indented sea-coasts, abounding with harbors, headlands, rivers and inlets, naturally produce an impulse towards the ocean, which, conspiring with the original adventurous character of the population, sends them roving from the arctic to the antarctic circle, till the wide world is laid under contribution by their enterprise. Their numerous streams and waterfalls furnish the cheapest means for moving machinery, and thus manufactories spring up, wherever, in their expressive phraseology, there is *water power;* and steam supplies local deficiencies of moving force. Ingenuity, conspiring with a general system of education, is excited under such culture, to produce numerous inventions, and hosts of young men seek their fortunes successfully abroad as mechanics, seamen, traders, instructors and politicians, who thus operate powerfully, and, we trust beneficially, on other communities.

Southern States.—The immense tracts of rich alluvium in the southern states—the mildness of the climate—the coasts, less abounding with safe inlets, and often modified by the action of the existing ocean, with a population not originally commercial, give a decided impulse to a vast agriculture, and a few great staples form the chief reliance of the landholders. It is easy to see, that this state of things grows out of the recent secondary, the tertiary, and the alluvial formations, which constitute the ocean barrier from Staten Island to Florida, and from Florida to Texas, extending inland towards the mountains.

---

* Bridgewater Treatise.

Western States.—In the west, the boundless fertile prairies and other tracts of productive soil conspire with remoteness from the ocean, to indicate agriculture and pasturage as the main employment of the inhabitants, while exhaustless beds of coal, limestone, plaster of Paris, and iron, and rich deposits of lead, and copper, and salt fountains both numerous and copious, furnish means for a manufacturing, as well as an agricultural population. These pursuits occupy the greater number of the people, while many find a profitable employment in navigating those immense inland seas, the great lakes—and the vast rivers, which run thousands of miles before they mingle with the ocean.

What geologist fails to perceive, that this state of things is the result of the immense lower secondary and transition formations which cover the western states, sustaining portions of tertiary, and like all countries, alluvial depositions. While New England produces granite, marble, and other building materials, of excellent quality, Pennsylvania, with the western and several of the southern and southwestern states, supplies inexhaustible magazines of coal, to prompt and sustain the manufacturing interests of this wide country, and to aid its astonishing navigation by steam, already of unexampled extent on its internal waters, and destined at no distant day, to compete, on the main ocean, in amicable rivalry, with our parent country.

Geological Treasures.—Our coal formations are unrivalled in the whole world, in richness and extent; our iron and lead are in the greatest abundance and excellence; Missouri has mountains of pure oxide of iron, that have no compeers, and there is a fair prospect that copper will also abound in the West. We have regat deposits of limestone and marble, of plaster of Paris, marl, and salt, and of building stones of almost every kind; our soils are so various in quality, and in geographical position, that almost every agricultural production is obtained in abundance. It is obvious then, that we have all the physical elements of national and individual prosperity, and that the blame will be our own, if we do not follow them up by proper moral and intellectual culture, which alone, can render them sources of public and private happiness.

Geological Deficiencies—Upper Secondary.—Of the upper secondary, below the chalk, and above the new red sandstone, lying

higher than the coal, we have no well ascertained strata: rocks of oolitic structure we may have, but it is not ascertained that we have the true oolite of England and continental Europe, nor have we traced the Wealden nor the Lias,* with their colossal animal wonders.

Equivalent of Chalk.—Chalk, properly speaking, appears to be absent from the United States, but there is an equivalent to the chalk formation, containing similar fossils, between the Delaware River and the shores of New Jersey, as well as in various places in the south, and, as we are recently assured, in Missouri.

Absence of Volcanoes.—The principal deficiencies in the geological formations of the United States, are in the absence of active volcanoes, as well as of most of the members of the upper secondary. However delightful, active volcanoes, with their earthquakes and eruptions, may be to speculative geologists, the sober, unscientific population, may well rest quite contented without them, satisfied to barter the sublime and terrific, for quiet and safety. Although the soils formed from decomposed lava are often fertile, and the vine flourishes, and the clusters smile most remarkably, on the flanks, and at the feet of the volcanic mountains of warm countries, these influences are too local to be of much importance to agriculture.

Within the United States proper, including the states and territories beyond the Mississippi, and east of the Alleghany Mountains, there is not, so far as we know, a single active volcano, nor even an unequivocal crater of one that is dormant. It remains yet to be decided, whether in and beyond the Rocky Mountains, quite to the shores of the Pacific Ocean, there are any active volcanoes within our parallels of latitude.

Both north and south of our limits, there are on the Pacific shores and the islands, numerous volcanoes, and it would be strange indeed, if there were none, within our extensive possessions on the same coasts.

Records of fire in the far West.—However this may be, there remains no doubt that fire has done its work, on a great scale, among the Rocky Mountains, and between them and the Pacific;

* It is plain that the lias, so called, in the West, is not the lias of England.

for all our travellers attest the existence of immense regions covered with scoriæ and other decidedly igneous products, as if there had been actual and vast eruptions, within a period too short for decomposition to have reduced those tumefied and semi-vitrified masses to soil.

Trap and Basalt.—Regular formations of trap and of basalt, with symmetrical columns, are common among and beyond the Rocky Mountains, and the rocks of this igneous family are frequent in many parts of the old United States. They abound in New England, New Jersey, and the Carolinas, and, as usual elsewhere, they protrude their dykes among other rocks. We are not aware that they have invaded the coal, as in Europe; but in New England, and especially in New Hampshire, they often divide the primary rocks, cutting even granite mountains from top to bottom; branching out, in many places, with numerous veins either dying away to extinction, or perchance, returning again to the main current after having cut off a portion of the invaded rock. The White Mountains of New Hampshire, abound with such features.

Similar intrusions are found in the mountains of Essex, Lake Champlain, New York, and in many other places, and the primary rocks on the coasts of Massachusetts and Maine, as well as in the interior, are wonderfully cut up, by invading veins and dykes of trap, basalt, porphyry, and even of granite itself.

It appears, also, that in the state of New York, there are similar intrusions of limestone into other rocks, including the primary, and not excepting granite.*

Tertiary Formations.—Our tertiary formations are exceedingly extensive, and are rich in fossils, chiefly of the middle and earlier eras. They bound a large portion of the sea coasts south of New England, quite to the Mexican gulf, and up the Mississippi and Missouri. Oceanic deposits are found also, extending hundreds of miles into the interior from the coasts, where, as well as near the sea, they furnish, in the calcareous marls, inexhaustible resources for agriculture. Even on the shores of New England, there are marine tertiary deposits, as at Gay Head, in Martha's

* See Professor Hall, in the Geological Reports for 1838.

Vineyard, and elsewhere in that vicinity, while there are, in every part of the United States, innumerable inland deposits of fresh water tertiary.

Boulders.—In boulders and rocks of transport, our country, especially in the north, northwest and northeast, abounds; vast regions of older secondary, and of transition, are occupied, more or less, by ruins of primary rocks, some of them of vast size, while the primary countries themselves, and the transition too, are marked by their own *disjecta membra.* We are precluded by our limits, from discussing the causes of their transportation, whether by floods, ice floes, or other motive powers.

Pebbles, gravel and sand, are found here as in other countries, transported and arranged by water.*

X. Classification and Nomenclature of Rocks.—We are gratified that our author, in the fifth edition of his work, has preserved the classification of rocks, to which the geological world has been so long accustomed. The changes that have been, from time to time, proposed by eminent men,—Brongniart, Conybeare and Philips, Lyell and others, have commanded our careful consideration, and we find them, as we might expect, since they are proposed by men of knowledge and talent, supported by powerful reasons; but still these reasons appear to us not sufficiently important to counterbalance the great inconvenience of novel terms, especially as there has been no decisive adoption or approbation of either of the new nomenclatures; nor are most of them free from the objection made to the established language—namely, that of implying theoretical views. It would be easy to prove this by instances cited in illustration; nor does the old language necessarily imply more of theory, than that there is among rocks an order of succession, and that there are also prevailing characteristics, distinguishing the classes of rocks from each other; and so much of theory as this must be admitted by any language that may be adopted, whether the terms are significant or not.

The terms primary, transition, secondary, tertiary, alluvial, diluvial, volcanic, trap, &c., are still in general use, and they are

* These remarks on American Geology, were inserted also, in an Introduction to Dr. Mantell's Wonders of Geology, first American edition, 1839.

retained even by those who introduce new terms, for the latter must, in order to be intelligible, be translated by means of the former. It is not necessary that every portion of a primary rock should, in its present form, be older than the masses that are generally superincumbent: granite may shoot its veins into the rocks that lie over it, without invalidating its general claim to a prior existence, at least in the form of materials, if not in the present mode of aggregation.

New terms are, with propriety, introduced into geology when they are needed, as into other sciences; thus, the vast secondary is divided into older and newer, or upper and lower; the immense tertiary is now separated into three divisions, older, middle, and newer, or in Mr. Lyell's language, eocene, miocene, and pliocene, and the latter of these is again subdivided into older and newer.

There are, however, limits to the utility of subdivisions; where they are very numerous and minute, and withal founded on theoretical considerations, they may become inconvenient, and produce the confusion they were intended to avoid. This was the fact in the minute details of the Wernerian language, while its leading terms were happily chosen.

If they were first contrived as a key to Werner's peculiar theoretical views, they no longer retain that peculiarity; they are now rather indicative of order and character in the formations, than of a theory of origin; and as this order and these distinctive characters really exist, they may, without inconvenience, be designated by these terms; nor do any terms that have been contrived, appear to us more unobjectionable.

We must concede the propriety of local names for local formations, especially where they are remarkable in their structure and contents. Such is the Wealden in the S. E. of England, the region which Dr. Mantell, and other English geologists, have so admirably illustrated; it is indeed a member of the upper secondary, but it is unique and most interesting in its geological characteristics. Such, also, to some extent, is the Stonesfield slate, a member of the lower oolite and middle secondary, but it presents organic remains, different, in some respects, from those of any other rock—at least, of any one that is coeval.

These local names have, however, been much multiplied, especially in England, where new terms are now proposed for subdivisions of the transition series, for which there exists, indeed, a commanding necessity, rendered apparent by the researches of Mr. Murchison, among the slates of Wales.

XI. Suggestions as to Geological Agents and Geological Theory.—Creation is the work of God. The earth, in common with the whole universe, unfolds volumes filled with proofs of intelligent, wise and benevolent design. The work bears the impress of a mind, omniscient—of energy, omnipotent—of skill, infinite—and of consistency and benevolence—without doubt real and perfect, although not always obvious to our limited faculties.

Without presuming to know, when or how, the act of creation was performed, we may, without presumption, inquire as to the physical powers that were put forth in arranging the materials of the earth, and as to the manner in which they may have operated to produce the grand and multiform results.

Granite—the deepest rock of which we have any knowledge, is not a mechanical deposit; it is made up principally of crystals, or of parts more or less crystalline in structure, mutually adjusted by salient and re-entering angles, or confusedly aggregated; presenting occasional cavities, lined by more perfect crystals. Every thing implies a previous state of corpuscular mobility, the particles having liberty of motion; and the only powers equal to the effect, are heat and electricity, aided by water and the saline, alkaline, acid, and other soluble chemical agents; these we now find abundantly in the constitution of the rocks, and they or their elements were therefore originally provided in the grand storehouse of created materials.

Comparative Agency of Fire, Water and Electricity.—The accumulation of geological evidence leaves no doubt of the prevalence of fire in the interior of the planet; the portion in actual ignition or fusion, in order to be sufficient to feed the host of volcanoes in various parts of the globe, must be very extensive, and the regularly increasing temperature as we descend into the earth—regular on the whole, although accumulating in different ratios, in different places aud countries, concurring with

the evidence of volcanoes, fully establishes the dominion of internal fire. Our knowledge of the powers that generate heat, in many modes of chemical and mechanical action, and more than all, by galvanism, renders it entirely credible, that any portion of the crust of the earth, whose origin appears to have been igneous, may have been really derived from that source. Any part of the interior may, therefore, have been melted, and if not now in ignition or fusion, it may readily pass to that condition by a transfer or increased energy of the powers which, even in our comparatively small experiments, are sufficient to generate, instantly, the most intense heat, in the most unfavorable circumstances.

It is extremely probable then, that heat may have wrought those wonders in our earth which demand extensive fluidity—fluidity by fire, rather than by water. Fire and galvanic electricity have this vast advantage over any fluid solvent, namely, that they can render any substances fluid, without the addition of more matter, to that which is to be thus made fluid; the materials themselves become, in a sense, the source of the heat needed to melt them, and it is without doubt that this agent may be sufficient to render the entire planet fluid. This may be granted, without deciding the question, whether it has ever actually been in this condition. Thus far we believe, that the opinions of most geologists will carry them at the present day; and if our views are different from those formerly expressed in connection with this work, the change is the result of conviction founded on adequate evidence.

It is now apparent that heat in the earth is not an accidental occurrence, like our fires kindled on the surface; it is not the result merely of transient combustion; it is an inherent and ever active principle, concentrated at one time in a particular region, and at another time in a different place; now, slumbering for ages, and then revived or transferred, but unextinguished and unextinguishable. It must have been prevalent in early ages in the deep interior of the planet, and indeed all that now bears evidence of an origin from fire, is by far the greater portion of the earth, while the depositions evidently produced by water, and by aqueous solutions, are but a very small film compared with the whole.

Water and Soluble Chemical Agents.—Leaving out of the question, for the present, the geological formations that are evidently aqueous, and are so regarded by all geologists, we are compelled to admit, that in the early periods of the planet the ocean must have prevailed far more extensively than now, if not universally; or, in other words, the existing dry land must have been under water. If granite had been melted under atmospheric pressure alone, or when there was no atmosphere, its surface would have been inflated and porous, like the upper current of lithoid lavas; but, if melted under the pressure of water, it may be of several miles in height, it would, on cooling from fusion, crystallize, and become as we see it, a solid mass. The same remark will apply to sienite, to porphyry, to trap, to serpentine, &c. which are admitted to have had an igneous origin.

Early and Present Ocean.—Now, what properties may we fairly suppose would have belonged to the waters that hovered over the yet embryo islands and continents, still immersed in their native element, before the elevation commenced, by which the dry land was made to appear, and what qualities may we not suppose the present ocean to possess at profound depths, where its pressure is great, and in those places where the heat may also be active and long prevailing.

Modified Properties.—Water, under such circumstances, must evidently be a fluid of very peculiar properties. It must contain all the chemical agents not only that are soluble in it, but also that are soluble in a compound fluid, consisting of water, and of other agents still more active. The acids would be solvents for the alkalies, the metallic oxides, and most of the earths; the alkalies would be solvents for alumina and silica; acids and alkalies may have alternately prevailed; and even if acids, alkalies, earths, and the other metallic oxides, had been present at the same time, and had formed salts, these compounds, so far as they were soluble in water, would also impart to the fluid peculiar solvent powers; while those compounds which were precipitated, would be thus removed, so as not to impede other agencies. In the constitution of mineral bodies, we find all the active chemical agents, oxygen, iodine, chlorine, fluorine; and doubtless bromine will be found; the acids and alkalies are abundant; soda exists

in great quantities; potassa is not unfrequent in minerals, and lithia is found in several. The alkalies are largely, and the alkaline earths are considerably soluble in water; all the earths except silica unite with acids, and even this is easily dissolved by hydro-fluoric acid. Thus all the metallic oxides are soluble, either in acids or alkalies; the metals and combustibles combine readily with oxygen, chlorine, iodine, bromine and fluorine; carbon* and other combustibles become soluble by combination with each other, and with the supporters of combustion.

If the elements came from the hand of the Creator in a state of freedom, their first action must have been attended with intense energy, and innumerable combinations and decompositions would have taken place, the great agents encountering each other at every turn, and thus developing a new order of things.

Solubility of Silica and Alumina.—It is worthy of remark, that quartz, feldspar and mica, the prevailing minerals in granite, gneiss, and mica slate, are composed mainly of silica and alumina. Now silica and alumina are (as already remarked) readily soluble in the fixed alkalies: alumina is soluble in acids; silica in hydro-fluoric acid, and this agent can render silica gaseous. There are notable quantities of potassa and soda in both feldspar and mica, and fluoric acid has been found in the latter; it appears therefore, that those solvents were present at the birth of these minerals, and entered into their constitution. Alkali exists in the earth in vast abundance, and thus even silica and alumina may have been provided with an appropriate solvent.

The solubility of all the existing materials that form the crust of the globe; their solubility either in their elementary forms, or in their proximate or complex combinations, is then a truth clearly demonstrable, and actually demonstrated.

Auxiliary Power of Heat.—The activity of chemical agents, especially if subjected to pressure, is much increased by a high temperature. There can be no reason why we should suppose, that those causes which now feed the fires of more than three hundred active volcanoes, were dormant in the youth of the planet. On the contrary, innumerable extinct or quiescent volcanoes, record the ancient energy and extent of internal fire, which would

* Carbon and chlorine do not unite *directly*, but they combine through the agency of hydrogen in olefiant gas and chloric ether.

operate both as an auxiliary to solution, and in its own proper agency by fusion.

Add to all this, the intense action of the deep seated fires which have melted granite and other igneous rocks, and we find ample evidence both of the direct and auxiliary agency of internal heat.

Before the emergence of the land from the ocean, all volcanoes must have been submarine, as many now are. They would all therefore act under vast pressure, a pressure not even approached by modern experiment, and the heat thus accumulated must have given great activity to water and to aqueous solutions of chemical agents.

Thus both mechanical and chemical laws conspire to produce solution and fusion on the greatest scale, and with the greatest energy. By fusion and softening by fire ; by solution and softening by water, and its dissolved chemical agents, which may have been even ignited under the enormous pressure of miles of ocean, we may suppose chemical depositions to have proceeded contemporaneously or in succession ; confusedly, as in granite, or in layers, as in gneiss and mica slate ; and the imbedded minerals of the primary rocks, the garnets, the staurotides, the tourmalins, the beryls, and others, whose elements were present, crystallized by their affinities, forming first the integrant atoms, whose progressive aggregation produced the beautiful crystalline solids, that in a peculiar manner adorn the early formations of the globe.

Water and fire and pressure, and all the great chemical agents, may thus have conspired, in acccordance with physical laws, in effecting the arrangement of the crust of the planet.

Violent movements were the natural result of this state of things. Igneous agency, the parent of earthquakes, acting beneath the rocks already formed, and beneath the incumbent ocean, would of course produce fractures, dislocations and distortions, tortuous flexions, injections of veins and dykes, heavings, subsidence and elevation of strata, called *faults* by the miners, and innumerable irregularities.

In the same manner many of the trap rocks were probably thrown up beneath the primeval ocean ; they broke through the strata and congealed above or between or among them, in ridges, peaks or flats ; or they were injected in dykes or veins, or driven, laterally, between the strata, rending them asunder, as if cleft by

wedges. When, after the emergence of land, they burst out beneath the atmosphere, they formed true volcanoes.

Inference.—While, by a vast accumulation of evidence, the claims of heat have been greatly and justly enlarged, and as regards the great mass of the globe, fusion has, by rightful authority, been substituted for solution, Vulcan has thus triumphed over Neptune; but the latter still enjoys no mean dominion, either in extent or in power. It is indeed impossible to explain geological phenomena without having recourse to both these mighty agents, the one ruling the immense interior kingdom, the other the external, through whose superficial territories the restless monarch of fire makes occasional and violent eruptions, establishing often only a transient sway, and after menacing universal destruction, retreating again to his hot domain, leaving merely the vestiges of his destructive aggression. At other times and places the irruption is sustained; age after age, subterranean thunder and agitations celebrate the victory, and a burning signal-light is hung out against the skies, the emblem of conquest by fire.

While we have vindicated the too much neglected effects of water and aqueous solutions in softening, modifying, or dissolving mineral bodies, we are free to confess that the solution of the entire planet, or even of its crust, in water or in any other existing solvent, is a supposition which no well instructed person would now venture to make. Sustained by the paramount authority of Werner, it was long a received doctrine of the geological schools, and it is perhaps not surprising, that his prevailing eloquence and the zeal of his numerous disciples, trained under the very sound of his voice, should have given extensive currency to this theory. Those who have been among the last to retreat from this untenable ground, have however no cause for mortification, since the converts to the Wernerian theory may find enrolled in their catalogue names of the greatest celebrity for talent, attainments, and moral excellence. This theory, as a whole, is now for the most valid reasons abandoned; still some important members of it will be always retained, and Werner, *clarum et venerabile nomen,* will be ever honored and revered.

XII. First condition of the Materials of the Globe.—Both geology and revelation are silent with respect to the first

condition of the materials of our planet, nor is it possible for us to decide the question how they first appeared. There is however no reason to suppose, that we see any thing as it was originally created. We are certain of this in relation to the rocks containing organized beings and fragments, whether the latter were charged with organized relics or not. This statement includes all formations except the primary or crystallized and igneous. Reasoning from the natural products of volcanoes, and upon the laws of crystallization, as applied to crystalline masses, as well as to individual crystals, no geologist hesitates to infer, that the crystallized and unstratified rocks have assumed their present appearances from the operation of natural laws, and consequently that the globe, as far as we can examine it, or infer its condition at profound depths, has been wrought over, and much of it again and again. Consequently, we cannot be certain that in this sense even granite is strictly primitive; but in relation to subsequent formations, it may be primary or anterior to them; as an igneous rock, it may have been melted in all geological ages, and consequently some of its injections and overflows may have been more recent than the newest secondary rocks, for it has been found penetrating and overlying chalk. This appears to be the most recent geological date which it has been proved to have attained. Still, it would not be surprising if it were found to invade and cover even the tertiary; we ought to be prepared for such discoveries, nor would they, if made, militate with our present views of geological dynamics. Farther than this we are hardly prepared to go, for if that which is granite below were to be erupted above, under only atmospheric pressure, it would assume some of the known forms of lava, and if ejected under the sea, it might take on the character of the traps or porphyries. In all vicissitudes of geological theory, it must ever remain true, that the materials of granite, considered as a whole, have always been below all other existing rocks, and consequently that they are prior in order of position, although their form of existence is not strictly primitive, nor can any thing among rocks be fully proved to be entitled to that name.

Mr. Lyell's name of hypogene implies formed beneath, which is in accordance with the ideas expressed above.

XIII. Possible modes and results of elementary action.—In the present state of chemical science, our elementary ponderable bodies are divided between combustibles, (metallic and non-metallic,) and supporters of combustion—of the former fifty, of the latter five; and if we extend the idea of combustion, as some authors are disposed to do, to other cases of intense chemical action, attended by the extrication of light and heat, we shall include the agency of the combustibles and metals upon each other, as well as upon the proper supporters of combustion, and also the action of the latter upon one another. For our present purpose, it is quite immaterial which view is embraced.

If we suppose that the first condition of the created elements of our planet, was in a state of freedom, and the globe being a mass of uncombined combustibles and metals, that oxygen, chlorine, iodine, bromine, and fluorine were added, it is obvious, that the reaction, awakening energies before dormant, would produce a general and intense ignition and combustion. Phosphorus, potassium and sodium would instantly blaze; the other combustibles and metals would follow in the order of their inflammability, and thus a general conflagration would be the very first step in chemical action. Water would be formed, the atmosphere would result from the mixture of its elements, the fixed and volatile alkalies, the earths, and stones, and rocks, the metallic oxides properly so called, the sulphurets and phosphurets, &c. of the metals and of the combustibles, the principal acids, the iodides, bromides, fluorides, and chlorides, alkaline, earthy and metallic, and ultimately the salts, besides many other compounds resulting either from a primary or secondary action, would be produced.

In such circnmstances, the imponderable agents, heat, light, electricity, magnetism, and other forms of attraction, would be inconceivably active—steam, vapors and gases would be suddenly evolved in vast quantities, and with explosive force; and the recently oxidated crust of the earth would be torn with violence. It is however obvious, that this intense action would set bounds to itself; for the chemical combinations would relent or cease, when the crust had become sufficiently thick and firm to protect the metals and combustibles beneath from the water and the air, and other active agents.

As we are merely stating the conditions of a problem, we forbear to descant upon collateral topics, or to pursue the primary rock formations through all their vicissitudes. We do not even aver that such events have actually happened; but philosophy is sober and rational when it assumes that their existence is consistent with the known properties of the chemical elements, and with the operation of physical laws. Supposing that such was the actual beginning and progress of things, it is obvious that the oxidated crust of the globe, would still cover a nucleus consisting of metallic and inflammable matter. Of course, whenever air and water, or saline and acid fluids penetrated to this internal magazine, the same violent action would recur at increasing depths, and the confinement and pressure of the incumbent strata, augmenting the effects a thousand fold, would in later ages, necessarily produce the phenomena of earthquakes and volcanoes.

Still, it is equally obvious, that every recurrence of such events, provided no cause of renewal can be indicated, must oxidize the earth deeper and deeper, and if the point should ever be attained, when water or air ceased to reach the inflammable nucleus, or if it were all oxidized, the phenomena must cease, and every approximation towards this point would render them less frequent.

Does this correspond with the actual history of the globe? Are ignition and convulsions less frequent now than in the early ages of our planet? The extensive regions, occupied by rocks of acknowledged igneous origin, but where fire is not now active, lend support to this hypothesis, which well accords with the views now generally adopted of the formation of granite. This hypothesis is perfectly consistent with the opinion that those galvanic powers which we *know* to exist—whose action we can command, and whose effects, having been first observed within the memory of the present generation, now fill us with astonishment, are constantly active in producing and renewing the phenomena of earthquakes and volcanoes, as both at earlier and later periods, they have been equally efficient in melting granite itself.

Metals and chemical fluids, with juxtaposition, in a certain order, are the common means by which we evolve this wonderful power. Even substances apparently dry and inert, will produce a permanent, and in proportion to the means employed, an energetic

effect, as in the columns of De Luc and Zamboni. Metals and fluids are not indispensable, for almost any substances of different natures properly arranged, will cause the evolution of this power. Whoever has witnessed the overwhelming brilliancy and intense energy of the great galvanic combinations of Davy, Children, and Hare, and considers how trifling in extent are our largest batteries, compared with the vast natural arrangements of earths, salts, metals and fluids, which exist beneath our feet, will not be slow to admit that this power may in the deep interior be incessantly and alternately evolved, mitigated, suppressed, revived, and augmented to tremendous intensity.

In our instruments, we see emanating from this source intense light, irresistible heat, magnetism in great efficiency, and a decomposing agency, which, by direct or intermediate action, commands all elements, and all combinations. The experience of a few years has added magnetism as a power at once the effect and the cause of electricity.

The latter, especially in the galvanic form, evolves immense magnetic energy, and magnets in turn give out electricity and produce all the effects of electrical and galvanic combinations—heat, light, or sparks and ignition, shocks, decomposition, and, by induction, even magnetism itself.

We have stated an hypothesis as to the condition of the elements when they were first created. We would not insist upon this, because we cannot know it to be true. But in assigning galvanic action as a cause of the internal heat of the earth, we propose a reasonable theory, and we provide not only for heat independently of combustion, but we may in this manner provide combustibles which may act chemically, and thus add to the effect without limit. The decomposition of acids, alkalies, earths, and other metallic oxides, is a familiar effect of galvanic action; their metals and combustibles are set at liberty, and some of them being inflammable both in air and water, elastic agents may be evolved, and being rarefied by heat, would produce violent mechanical action. The first principles of this hypothesis are established by experiment, and nothing is really hypothetical but the application to the phenomena of internal heat and of earthquakes and volcanoes.

It is a peculiarity of the present view, that causes are provided which admit of indefinite continuance, and of unlimited renovation, and there appears no reason why the phenomena should ever cease. It has therefore the great Newtonian requisites of a good theory: *its facts are proved*, and *the theory is both true and sufficient*. In its application to volcanoes, it has this additional advantage, it embraces all that is possible in other theories. Coal, lignite, sulphur, petroleum, hydrogen gas, and fermenting pyrites, may all contribute their quota of power to the production of volcanoes, although the united effect of all these must, if it be operative at all, be very trivial. Heat, light, electricity, and magnetism, may produce endless decompositions and recompositions; burnt substances by galvanic energy returning again to their combustible condition, will burn anew; elastic fluids will be evolved in unlimited quantities, and all the violent mechanical effects which their action is known to produce will succeed; these are among the known and familiar effects of this power, and all the materials necessary to render it active are existing in the earth on a scale of immense extent. The present hypothesis does not exclude the subsequent action of water, in dissolving chemically, or disintegrating mechanically, the crust of the globe; for water, fire, and all the great chemical and mechanical agents mutually cooperate.

The cause now indicated is sufficient for all the phenomena, and this cannot be said of any other that has been, or, in the present state of our knowledge, can be named. We may venture a step farther; it is certainly possible,—perhaps it is not improbable, that the light and heat of the sun and of the fixed stars may have a similar origin. To the eye of philosophy, as well as to vulgar apprehension, the sun is an ignited body, and we know not of any power but the electrical that can perpetuate this condition. It is not necessary to speculate as to the mode of excitement, but we may remark, that fluids are not indispensable; the power may be evolved from dry substances, and even between good conductors, if heat be applied in the beginning; electricity may produce heat, and heat may excite electricity, and both have the most intimate and reciprocal relations to magnetism. Thus a circle of agencies is provided which being mutually causes and

effects may continue to operate in an endless cycle whose termination will not be fixed by the exhaustion of phyical power, which never tires nor grows old, and will cease to act only when the Creator shall fix its limit and annul the fiat that called it into being.

XIV. Relation of Geology to the early Scripture History.—In this country, the cultivation of scientific geology is of so recent a date, that many of our most intelligent and well educated people are strangers even to its elements; are unacquainted with its amazing store of facts, and are startled, when any other geologieal epochs are spoken of than the creation and the deluge. But, it is beyond a doubt, that there are innumerable and decisive proofs of successive revolutions, and of a gradual progress in the course of geological events, implying, on the whole, a regular order in the formation of the crust of the planet, which events necessarily imply much time, and cannot be referred, exclusively, to any course of diluvial action. It is impossible, to refer to this cause, rocks containing consolidated water-worn ruins and fragments, and organized remains, entombed in the firm strata and mountains. The fossil organic kingdom presents a vast field of observation and instruction, and it is less known, even to the greater number of intellectual persons, than almost any department of knowledge. None but geologists study it with diligence, and none who have not made themselves masters of the facts, are qualified to judge of their importance, and of their bearing. To understand the subject, we must study in the fields, in the mines and mountains, or, as an imperfect substitute, in the cabinet. Persons who are entirely ignorant of this species of information, are destitute of the means of forming a correct judgment, they neither know the facts, nor can they compare one truth in geology with another, so as to estimate their mutual relation. On this subject, it is, therefore, very difficult to find access, to many minds, otherwise enlightened, and habituated to receive and weigh evidence, with candor and intelligence. The obvious reason is, that they are not in possession of the first elementary conceptions; and when the facts are stated, if they are not denied, they are neglected, because they are inconsistent with their habits of thought, and because they make no distinct impression,

they are supposed to be dreams or pictures of the imagination; thus they fail to bring that conviction to the mind, which must always be the result, when they are fully understood and realized.

In this country, where the moral feeling of the people is identified with reverence for the Scriptures, the questions are often agitated by intelligent persons,—When did the great series of geological events happen? If the six days of the creation were insufficient in time, and the facts cannot all be referred to the deluge of Noah, to what period, and to what state of things shall we assign them?

This is a fair topic of enquiry, and demands a satisfactory answer; an answer, which is given by the whole series of geological discoveries, and the question will never remain of doubtful issue in the mind of any one who has fully studied and mastered them: but they must be studied profoundly and not superficially. The subject of geology is possessed of such high interest, that it will not be permitted to slumber; it will proceed with increasing energy and success; a great number of powerful minds and immense research are now employed upon it, and many collateral branches of science are made tributary to its progress. Its conclusions have been supposed to jar with the Scripture history; this is contemplated with alarm by many—with displeasure by some, and possibly, by a few with satisfaction; but there is no cause for either state of feeling: the supposed disagreement is not real; it is only apparent. It is founded upon the popular mistake, that since the creation, the deluge and volcanic eruptions, with the convulsions of earthquakes, are the only causes that have produced important geological changes; they believe that this world was formed substantially as we now see it, and if they have any knowledge of its immense and various deposits, they suppose that they were made in a very short period of time. Both these are fundamental errors, which have misled both the learned and the unlearned, and they are still extensively prevalent.

Although the materials were created by almighty power, they were evidently left to the operation of physical laws, which laws also affected, more or less, the fate of the various races of plants and animals that were successively called into existence. But as already remarked, there is no reason to believe, that any part of

the crust of the earth, reaching even to a fathomless depth, is now in the condition in which it was originally made; every portion has been wrought over and brought into new forms, and these changes have arisen from the action of those physical laws which the Creator established, and which are as truly his work, as the materials upon which they operate. The amount of time is the only difficulty, and this will vanish before an enlarged and reasonable view of the whole subject, comprehending also a just estimate of the evidence.

Nature of the evidence.—The evidence is the same which is readily admitted as satisfactory in the case of historical antiquities.

Roman coins, weapons, personal ornaments, utensils, baths, roads, camps and military walls, and defences of various kinds, have been frequently discovered in Britain. They are ascertained to be Roman, by their resemblance to, or identity with, the acknowledged productions of that remarkable people, as still existing in Italy and the adjacent countries, the ancient seat of their dominion. Had Julius Cesar and the other historians and writers been silent as to the invasion of Britain, and as to the dominion, which, for more than four centuries the Romans sustained in that island; still, could any one, acquainted with the facts, hesitate to believe, that they had not only visited Britain, but also remained there, for a great length of time, as conquerors and masters. Had all historical knowledge of these events been lost, would not the antiquary who examined the relics, and who also extended his observations to other countries where similar things are found, with perhaps the addition of splendid aqueducts, temples, and amphitheatres, pronounce that they had all evidently originated from one and the same people, and would he not, without hesitation, pronounce them to have been highly civilized, warlike and powerful; and that their epoch was one of considerable antiquity.

At this moment, there exist in some parts of England, and in various parts of Europe and Asia, ancient barrows or sepulchral mounds, some of them of stupendous size; similar structures are found in North America, and also stupendous forts, which, in Ohio and Kentucky, and other western states, amaze and confound the observer.

These structures enable us to realize the supposition just made respecting the Romans, and compel us to say, that all these massy mounds and forts, were the work of unknown races of men, on whose history even tradition sheds not a ray of light, and we are left in profound ignorance, as to their origin.

In relation to geology, it is easy to make the case still stronger. When, in 1738, the workmen, in excavating a well,* struck upon the theatre of Herculaneum, which had reposed, for more than sixteen centuries, beneath the lava of Vesuvius; when, subsequently, (1748,) Pompeii was disencumbered of its volcanic ashes and cinders, and thus two cities were brought to light; had history been quite silent respecting their existence, as it was respecting their destruction;† would not all observers say, and have not all actually said,—here are the works of man, his temples, his forums, his amphitheatres, his tombs, his shops of traffic and of arts, his houses, furniture, pictures, and personal ornaments, his streets, with their pavements and wheel-marks, worn in the solid stone, his coins, his grinding mills, his wine, food, and medicines, his dungeons, and stocks, with the skeletons of the prisoners chained in their awful solitudes, and here and there the bones of a victim, who, although at liberty, was overtaken by the fiery storm, while others were quietly buried in their domestic retreats; the falling cinders and ashes even copied, as they fell, the delicate outline of female forms, and having concreted, they thus remain true volcanic casts to be seen by remote generations.

Because the soil had formed, and grass and trees had grown, and successive generations of men had unconsciously walked, tilled the ground, or built their houses, over the entombed cities; and because they were covered by lava or cinders, does any one hesitate to admit, that they were once real cities, that at the time of their destruction they stood upon what was then the upper surface, that their streets once rang with the noise of business, their halls and theatres with the voice of pleasure: that, in an evil hour, they were overwhelmed by a volcanic tempest from

---

* Earlier excavations had been made and three female statues discovered.

† In the histories of those times, it is only said, in general terms, that cities and villages were overwhelmed.

Vesuvius, and their name and place, for almost seventeen centuries, blotted out from the earth and forgotten.

The tragical story is legibly perused by every observer, and all alike, whether learned or unlearned, agree in the conclusions to be drawn. When moreover, the traveller of the present day sees the cracks in the walls of the houses of Pompeii, and observes that some of them have been thrown out of the perpendicular, and have been repaired, and shored up, he learns that the fatal convulsion was not the first, and that the doomed cities, must have been before shaken on their foundations, by the throes of the laboring earth.

To establish all this, it is of no decisive importance that scholars have gleaned, here and there, a fragment from ancient Roman classics, to show that such cities once existed; and that they were overthrown by the eruption of the year 79 of the Christian era, which gave occasion for the interesting letter of the younger Pliny, describing the death of his uncle, while observing the volcanic phenomena, his philosophical curiosity having cost him his life. In such cases, the coincidences of historical and other writings, and the gleanings of tradition, are indeed valuable and gratifying; they are even of great utility, not in proving the events, for of them there is a record, which cannot deceive, but in fixing the order, and the time of the occurrences. The nature of the catastrophe, which buried the devoted cities, is however perfectly intelligible, from the appearances themselves, and needs no historical confirmation. No man ever imagined that Herculaneum and Pompeii, were created where we now find their ruins; no one hazards the absurd conjecture that they are a lusus naturæ, but all unite in giving an explanation consistent alike with geology, history, and common sense.

Application of the Evidence.—In the same manner then, we reason respecting the physical phenomena of our planet, and here, even at the hazard of some repetition, we shall make a statement of facts, to illustrate this most important argument, which will demonstrate that geological evidence is of the same nature with that just cited, and that the most revered documents cannot be more decisive in relation to civil history, than geological facts are with reference to the natural history of the earth.

The earth then is full of crystals and crystallized rocks; it is replete with the entombed remains of animals and vegetables, from entire trees to lichens, fuci and ferns—from coal beds to mere impressions of plants; it is stored with animals, from the minutest shell fish, and microscopic animalculæ, to gigantic reptiles; it is chequered with fragments, from fine sand to enormous blocks of stone; it shews on the joining surfaces of many strata, and especially of the sandstones, the delicate flexions, produced by undulating water, when the materials were loose as they are now on the sea-shore; it exhibits in the materials of its solid strata, every degree of attrition, from the slightest abrasion of a sharp edge or angle, to the perfect rounding which produces globes and spheroidal forms of exquisite finish; it abounds with dislocations and fractures; with injections and fillings up of fissures with foreign rocky matter; with elevations and depressions of strata, in every position, from horizontal to vertical; it is covered with the wreck and ruins of its upper surface; and finally, its ancient fires, sometimes for variable periods, partially dormant and relenting, have never been extinguished, but still struggle for exit, through more than three hundred volcanic mouths. The present crust is therefore only the result of the conflicting energies of physical forces, governed by fixed laws; its changes began, from the dawn of the creation, and they will not cease till its materials and its natural powers are annihilated.

Instances.—They are innumerable, and are every where at hand; every system of geology unfolds them; our author's preceding volume is rich in such facts, and it remains only to illustrate our position by a few examples, duly connected, to sustain the argument, for which purpose they are added.

Fossil Fish of Mount Bolca.—The beautiful fossil fish,* more than 100 species of which are found in marly limestone, in Mount Bolca, near Verona in Italy, inform us that they were once living and active beings; before those hills were deposited, and when the waters stood over the place where, in the bottom of the sea, the fish were entombed, the rock which contains their skeletons

* Already cited in the general sketch; from this celebrated locality there are splendid specimens in the cabinet of Yale College.

was formed around them, doubtless in the state of a calcareous and argillaceous sediment; this calcareous stratum (perhaps itself thrown up by a volcanic heave, and thus suddenly enclosing the fishes) was then overwhelmed by a submarine eruption of molten rock, and the heat was not communicated through the bad conducting substance of the marl, to the destruction of the organic forms; then again, and still on the bottom of the sea, the calcareous rock was formed anew with its enclosed fish; again the molten rock flowed over the calcareous marl, and so on in several successions. But this is not all; this remarkable formation is now 50 miles from the Adriatic, the nearest sea, and it rises 1200 feet above it. It is plain then, not only that the whole was successively formed beneath the ocean, but that the hill, with the country to which it belongs, was afterwards raised by the power of subterranean heat, thus emerging from the surrounding waters, and ages since becoming dry land.

To illustrate this case, we will state that in the waters of the harbor of Newport, in Rhode Island, there are one hundred and thirty or more species of indigenous fishes;* now suppose an irruption, as from land torrents or a volcanic movement under the waters, were to throw suddenly upon them, such a mass of sedimentary mud, that they were to become entangled and suffocated on the spot; they would of course remain, and the materials might, by pressure and time, become consolidated around them. Were the bottom of the sea to be afterwards elevated into dry land, on opening the bed, there would be found a true Bolca quarry of fossil fish. Excepting the overflow of igneous rock and the repetition of the fish deposit, and of the fire rock, the cases appear exactly alike.

The Bolca fish present only one example among thousands in Italy and Sicily, of the emergence of mountain ranges, whose flanks for a thousand feet or more in height, as on the Apennines, or two thousand as in Sicily, are replete with the shell fish and other molluscous animals of the Mediterranean.

Organic Remains in Early Rocks.—In very early, and often deeply seated rocks, usually called the transition, coming imme-

---

* As ascertained, from the fishermen, at the instance of the late President Dwight, by my brother Gold S. Silliman, then a citizen of Newport.

diately after the primary, we find the first traces of organized beings; the perfect impresses of plants, with the earliest coal, and both the forms and the entire mineralized bodies of millions of animals; the deposition of these rocks was therefore cotemporary with, or subsequent to, the creation and propagation of the organized beings whose impresses or whose forms they contain, and it is self-evident, that these rocks could not have been deposited prior to the date of the animals and vegetables included in them.

In many cases both the plants and animals lived and died at or near the places where they are found entombed in the rocks; for often they present few or no marks of violence, or of accident; their delicate parts are often perfectly preserved; animals, with their organs entire, and plants with their fibres and leaves in full expansion.

Occasionally, however, we find one stratum with its included mineralized organic bodies entire, and a contiguous one having them more or less broken, mutilated and dispersed. It is therefore evident, that in early ages, as now, organic relics were transported and broken by currents and other aqueous movements, and by atmospheric agitations, and that perfect repose was only occasional and existed in peculiar circumstances, while between the extremes of great movements and entire quiet, there were, as at the present time, many intermediate stages.

Both the plants and animals belong to races which are no longer found alive, or if *analogous* races exist, they are related to the ancient ones only by class or genus, and not by species. Orthoceræ and trilobites are found among the most ancient animals, and zoophytes, shell fish, and other molluscs are common. Madrepores and crinoidea abound in the early rocks. Sometimes, strata rich in entombed animals, occupy great districts of country. In the transition marble for instance, animals reposing in the bowels of mountains, miles from day-light, often form almost the entire mass, and they are so firmly united to the rock, as to constitute a part of its substance. Many of the architectural marbles owe much of their beauty to imbedded animals, myriads of which lie almost in absolute contact; the matter of the rock between them, only filling up the void occasioned by their angular and confused positions.

The trilobites had a jointed articulation, could bend their bodies like a lobster, and we find them sometimes doubled, and sometimes expanded, as they lie in the rocks. Dr. Buckland has shewn that the eye of this animal was furnished with 400 lenses, adapted to a wide range of vision in clear water, and consequently it was not fitted to live in the turbid ocean formerly supposed to belong to this geological period—the imaginary chaos. Dr. Buckland's Bridgewater Treatise is a classic on organic remains, and no one having the knowledge and giving the attention necessary to comprehend his fine course of illustration and argument, can fail to find in his book a moral and physical demonstration of the highest order; physical, as proving the progressive formation of the crust of the earth through a long course of ages, and moral, as evincing the wise and benevolent design which is irresistibly inferred from the work of progressive creation and arrangement.

We have already mentioned the fossil fishes below the coal, and in the deep transition rocks still lower down. The former opinion that the early animals were exclusively very simple in their structure, appears therefore, no longer tenable. Still it is true, that as the creation advanced, higher orders of both animals and plants were called into being, while animals of simple structure are also continued to the present time.

Possible Mode of Consolidation.—There is little difficulty in understanding how the marine animals—for example, the crinoidea and corals that fill, more or less, the transition limestone of the Peak of Derbyshire, and the limestone of many portions of the West in the United States, came to be thus entombed. We cannot doubt that the animals received their existence, and lived and died in the ocean, and that, at least at the time of their death, it was full of calcareous carbonate, either in solution or in mechanical suspension, or both. When they died, they of course subsided to the bottom, and were surrounded, as they lay, by the concreting calcareous matter. Multitudes of them were present, at the same time and place, in all the confusion of accidental position, and therefore were enveloped, just as we find them, in every imaginable posture; the interstices were filled by the lime, and this being more or less chemically dissolved, produced a firm sub-crystalline mass, a section of which shews us the animals sawn through, and admitting of a polish, like the rest of the rock.

If we could suppose that our common clams and oysters, that lie in the mud of our harbors and inlets, were to become solidified into one mass, along with the matter which envelopes them, the case would not be dissimilar; only they would be enveloped in earthy, instead of crystalline matter, and the rock formed from it would be referred to the most recent secondary, or to the tertiary, unless its texture were afterwards altered by igneous agencies, by infiltration of dissolved matter, or other causes, and even then, its geological age would be decided rather by its organic remains, than by its mineral texture.

It is easily understood, also, how a new stratum, either of the same or of different constitution, may be deposited upon a previous one, and with it, the bodies of the animals that lived and died in the fluid, by which it was covered; and these might be the same animals with those of a previous stratum, or of a different order, it being understood that, in the case of marine animals, each successive stratum was, in its turn, the bottom of the existing ocean, and also the upper or last consolidated layer of the crust of the earth, as it then was at that place. A similar course of reasoning will apply to fresh-water deposits.

With respect to marine and aquatic animals, the temperature, and perhaps the mineral contents of the waters, appear to have been, at different periods, adapted to the support of different races, which were therefore called into existence, and thus, when they died, their remains became successively solidified.

There was not, however, an entire extinction of all the animals of a particular race; a multitude were entombed, as is proved by their remains, but the species often survived to another epoch or to other epochs, sometimes through a cycle of changes; in the mean time, new races were created and became petrified in the forming rocks: again perhaps, the diminished race peopled the waters anew, and their relics were solidified in another deposition, and so on in succession.

Whether animals and vegetables were deposited in the ocean, or in seas, in lakes, rivers or estuaries, it is easy to imagine, that if all the causes necessary to produce the events were to be brought into successive operation, they might follow each other in the order supposed; and that this was the fact, cannot be reasonably doubted, any more than that an edifice, having granite

for its foundation, sandstone for its basement, marble for its superstructure, wood for its roof, and lead, zinc or iron for its covering, was actually constructed by the architect, and connected in that order by his intelligent design.

The great truths of geology are few, simple and intelligible; needing nothing but the application of a sound judgment, enlightened by science, to the accurate observation of facts; the order of their succession can be often ascertained, and not unfrequently the proximate causes and the immediate circumstances can be discovered and satisfactorily explained.

It is a supposition, altogether inadmissible, and unworthy of a serious answer, that the animal and vegetable races, entombed in such profusion, and buried often under entire mountain ranges, or firmly cemented into their very bosom, were created as we find them; and still more preposterous is the suggestion sometimes made, by those ignorant of geology, that there are no real organic relics, but only illusory resemblances to animals and plants. Both suggestions are absurd, and evince only profound ignorance. To any person well informed in geology, it is quite superfluous to assert that organic relics were once living beings, performing the part belonging to their respective races, and that at their death, or soon after, they were consolidated, in the then concreting and forming rocky strata, or that they were, in various instances, overwhelmed by igneous or diluvial catastrophes.

Animal Remains in Secondary and other Rocks.—The older secondary rocks often abound in shells of molluscous animals, principally of extinct genera, and there is a progression through the more recent strata, exhibiting a greater and greater approximation towards the more complicated structure of the most perfect animals; while the newer rocks of this class, and of the strata that lie upon them, including the tertiary, contain reptiles, fish, and even birds, and terrestrial quadrupeds.

Saurians and Lizards.—The extinct saurians or lizards, mentioned already in our general sketch, appear to have been mainly coeval with the period between the coal and the chalk, or the early tertiary. They were the most conspicuous animals of that time, and were evidently very numerous. Several genera, including many species, and a great number of individuals, have been discovered, and among them are the most colossal bones that have

hitherto been found, anterior to the middle tertiary, or perhaps to any periods.

These ancient saurian families, namely, the crocodiles, the ichthyosauri or fish lizards, the megalosauri or great lizards, the plesiosauri or animals resembling lizards, and several more, have been found in the middle and recent secondary tertiary rocks, especially of England and France, and some of them have been discovered in this country.

The megalosaurus is found in limestones and sandstones lying higher than the lias, and the ichthyosaurus and plesiosaurus, in many of the strata above, and in some of those below that rock.

The fossil crocodile appears to have been, anciently, as at present, an inhabitant of fresh water, and of rivers. In the West Indies, according to De la Beche, the crocodiles frequent muddy, and sometimes brackish ponds; and in shallows, they often remain for hours, with the tips of their noses out of water. The crocodile has been continued, perhaps, from the new red sandstone—certainly from the lias, to the present time—and as its remains often occur in the interval, it appears to have been a tolerably constant inhabitant of our globe.

The organization and habits of crocodiles do not enable them to contend with the agitations of the sea, which they shun. It would seem, however, that the organization of the ichthyosauri, and perhaps of the plesiosauri, would enable them to swim in the waves.

With the solitary exception of two species of the opossum, found in the Stonesfield slate near Oxford, England, no viviparous vertebrated animal has been found below the chalk. The Stonesfield slate belongs to the older rocks of the oolitic series, and lies above the lias.

The remains of the saurians indicate animals of various size, from a yard or two to twenty, forty, fifty, and seventy feet or more in length. Being generally amphibious, there is every reason to believe, that when only portions of England, in the form of islands, stood above the water, these animals swam and sported about in the interlocking waters of early Britain, or basked upon the beaches of its seas and estuaries, while the terrestrial lizards, some of which were of gigantic dimensions, either preyed on other animals, or cropped the exuberant tropical vegetation of

a glowing climate, that flourished either on the dry land or along the fenny and sedgy shores.

The iguanodon, (so called from the resemblance of his teeth and form to those of the iguana of the West Indies,) was an herbivorous reptile, and appears to have attained the length of seventy or eighty feet or more, with a height of nine or ten feet. Still, his remains are interred in solid ferruginous sandstone, far below the chalk, and probably more than two thousand feet beneath the upper strata of chalk and tertiary, that were subsequently formed over him, most of which have been swept away by diluvial action or by other causes.

In July, 1832, another saurian was discovered in the sandstone of Tilgate Forest.* It is described and figured by Dr. Mantell in the Geology of the South East of England. The reptile is named the *hylæosaurus*, or Wealden lizard. Vertebræ, ribs, coracoids, and other bones were found, either in connexion or in juxta position, making an imposing mass, and very firmly cemented in the sandstone. The animal is supposed to have been twenty five feet long.

The vegetable remains, as well as the fishes and shells, and rolled stones, that are found entombed in the same strata, prove that they were once the upper surface, and formed part of a vast estuary, which was subsequently buried by the marine formation of the chalk and its attendant strata.

Early Animals, Vegetables, and Coal.—Among the primary rocks there are no traces of vegetation any more than of animal life. According to De la Beche, wood and terrestrial plants are found in most rocks, not only from the old red sandstone upwards, but in the transition beneath; proving, that dry land must have existed, more or less, previous to, or at the time of the formation of most of these rocks. We may suppose, therefore, that ponds, lakes and rivers, existed also.

It would appear, from the relics of the periods immediately succeeding the transition rocks, that vegetation had increased prodigiously upon the earth, and that there were even trees and forests upon those parts of the surface that had become sufficiently dry.

---

* Subsequently at a later geological period, that of the green sand beneath the chalk at Maidstone.

Bituminous coal was formed from submerged and inhumed vegetables, among which, cryptogamous plants, whose vestiges are numerous in the coal mines, were conspicuous.

Coal, with all its alternating and attendant strata of shales, sandstones, limestones, clays, iron ores, puddingstones, &c., is often found repeated several times in the same coal basin or coal field; in extreme cases fifty, sixty, or seventy times or more; and the mines are occasionally worked to a great depth, (even to a thousand feet in some places in England.) It is plain, therefore, that no sudden and transient event, like a deluge, could have produced such deposits, although it might bury wood and trees, which, in the course of time, might approximate to the condition of lignite or bituminized, or partially mineralized wood, which is often found under circumstances indicating a diluvial origin.

Two very interesting facts have been recently observed in this country, illustrating the origin of coal from vegetables. Peat has been found in Maine, converted into coal; large trees have been discovered buried beneath the alluvial sand and clay of the Mississippi; some of them retain the marks of the axe, but are changed in part into coal, and still present perfect wood in parts of the same log.—Amer. Journal, Vol. xxxv, Dr. C. T. Jackson—Prof. Carpenter.

Arborescent plants, and their branches and roots, are often found in the coal formations, and in their sandstones, &c., thus proving that the gigantic vegetables were sometimes embraced in those deposits.

Early existence of Trees.—It had been supposed, that the plants which have contributed to the formation of coal were generally succulent, with little or no firm woody fibre. It appears, however, from two memoirs by H. Witham, Esq., of Edinburgh, that large trees, strongly resembling the Norway fir and the yew tree, existed, even anterior to the deposition of the great bituminous coal field of the Lothians, around Edinburgh. Near that city, in 1826, a fossil tree was discovered, three feet in diameter at its base and thirty six feet long, lying nearly horizontally between the strata of sandstone. Its composition was carbonate of lime 60, oxide of iron 18, carbon 9, alumina 10.

In the quarry of Craigleith, near Edinburgh, another fossil tree has been recently uncovered, whose geological position is in the mountain limestone, and considerably below the great coal basin of the Lothians. Its elevation is seventy five feet above the level of the sea, and its roots were in the bottom of the quarry. The length of the stem was forty seven feet—a large branchless trunk,—in some parts much flattened, so as to afford an elliptical section. At the largest place, its diameter was five feet by two, and at the smallest, nineteen inches by sixteen. Its branches, and many feet of its top, are gone; it was probably sixty feet long, and the incumbent mass of sandstone appears to have been one hundred feet thick; the bark is converted into coal. The composition of this tree is, carbonate of lime 62, carbonate of iron 33, carbon 5, with the specific gravity 2.87. It was a conifer.

In the great coal field of the North, in Britain, fossil plants are usually found lying parallel to the strata, but much broken and compressed, and their parts scattered; but some vigorous plants, generally Sigillariæ, appear to have been so strong as to resist the torrents and to remain in their natural position.

It results from Mr. Witham's discoveries, that gymnospermous phanerogamic plants are much more frequent in the coal formations than has been imagined, and that proper trees, of true ligneous fibre, and of great size, existed even earlier than the bituminous coal.*

Fossil Forest of Portland.—In quarrying in the oolite limestone of the island of Portland in the English channel, the workmen discovered an ancient soil, which they called the *dirt-bed*, and it still bears that name, or sometimes *dirt and black dirt*. It is from twelve to eighteen inches thick, and darkened by lignite. It contains numerous rounded stones from three to nine inches in diameter. In this dirt bed are buried many silicified trunks of coniferous and tropical trees, the latter, palm-like in character, and allied to the Zamia and Cycas. They were evidently fossilized where they grew, as the stumps of the trees stand erect for a height of from one foot to three, and in a single instance even six, with their roots attached to the soil, and about as near to each other

* American Journal, Vol. xxv, p. 109.

as in modern forests. The carbonaceous matter is most abundant around the stumps and around the remains of the fossil Cycadeæ. The dirt bed contains also prostrate silicified stems of trees, partly buried by the black earth and partly by a calcareo-siliceous slate that covers the dirt bed.

Although the fragments of the prostrate trees are rarely more than three or four feet in length, still by uniting many pieces, trunks have been restored to the length of twenty to twenty three feet, or, as Dr. Mantell states, upwards of thirty feet, the stems being imbedded from seventeen to twenty feet, and then forked; the diameter of these near the root is about one foot, and the descent of the roots into the subjacent Portland stone, shows that its strata were soft and impressible when these trees grew. The calcareous slate which covers the trees, was deposited with tranquillity, and forms swelling masses over the tops of the stumps. These strata are found elsewhere: at Lullworth cave, in Dorsetshire, they are inclined at an angle of 45°, and still sustaining the trees in an inclined position, but at right angles to the strata.

From these facts it is inferred that the oolite, full of marine shells, became dry land—its upper surface then became covered by a forest in which grew the tropical plants, the Zamia and Cycas; that the land, with its forests, sank and was submerged beneath a body of fresh water, which deposited a calcareous sediment, with fluviatile limestones, (the Purbeck beds,) deposited quietly, as the water was not disturbed. Two other carbonaceous beds have been found below, and one of these containing Cycadeæ. Mr. Lyell has summed up these changes thus:* "There must have been first, the sea, in which the corals and shells of the oolite grew; then land, which supported a vegetable soil with Cycadeæ; then a lake, or estuary, in which fresh-water strata were deposited; then again land on which other Cycadeæ and a forest of dicotyledonous trees flourished; then a second submergence under fresh water, in which the Wealden strata were gradually formed; and finally, in the cretaceous period a return over the same space of the ocean."

---

* Elements, p. 358.

Then might be added the tertiary strata, both marine and fresh water, and finally the alluvial and diluvial.

To imagine, adds Mr. Lyell, such a series of events, will appear visionary and extravagant to some who are not aware that similar changes occur in the ordinary course of nature; and that large areas near the sea are now subject to be laid dry, and then submerged, after remaining for years covered with houses and trees.

More recent Fossil Trees and Plants.—Among the more recent secondary rocks, vegetables increase in quantity and variety as we approach the tertiary, in which we find inhumed wood in the form of lignite, or bituminized wood, or wood slightly mineralized; eventually we find wood unchanged, although inhumed, and finally peat and living plants; and thus we trace the vegetable families, from their commencement on the borders of the primary, quite down to our own times. In the loose sand, gravel, and detritus, we often find trees, at every depth, between the surface of the ground and the fixed rocks below; the surface is often covered by boulders of travelled stones, and the deposition is evidently diluvial.

Organized Remains deposited from Water, but not from a Transient Deluge.—It is scarcely possible to doubt, that the process of animal and vegetable decomposition in a mineralized state, described above, was that which really happened. Whatever may have been the operations of fire at preceding or subsequent periods, it is impossible that it should have been concerned in the immediate formation of the mineral strata, which contain numerous organized remains. Animals or vegetables could never be produced or sustained in the midst of fire; and indeed, it is quite incredible, that strata, containing their relics, were ever melted; nor is it easy to imagine, that they could be even softened, in any great degree, without destroying or materially deranging the organized structure.

Strata of shale or clay might, indeed, be baked without fusion, so as to assume a stony hardness, and still preserve organic impressions. Thus we have observed a common hard baked brick, lying in a pavement, bearing a distinct and beautiful impression of a scallop shell, (Pecten;) the shell was gone, being doubtless destroyed by the fire, while its impress remained. Strata that have

been ignited may, therefore, retain the forms of organic bodies, which would of course be destroyed by the heat.

This fact is indeed fully illustrated by every ornamental impression made by a mould or die upon the clay of unbaked pottery or porcelain; it remains indelible and unalterable after passing through the furnace.

It appears evident also, that the mineralized plants and animals of the solid strata have not been collected in these situations by any sudden and local, or even general catastrophe; for, as an author remarks, "among the immense number of fossil shells, many are remarkable for their extreme thinness, delicacy and minuteness of parts, few of which have been injured, but on the contrary they are, in general, most perfectly preserved." Among the plants of the coal formation, situated sometimes hundreds and thousands of feet below the surface, and covered by many beds of solid rocks, their leaves, many of which are of the most tender and delicate structure, are often found fully expanded, in their natural position, in regard to the rest of the plant, and laid out with as much precision as in the *hortus siccus* of a botanist. It is often true that the minutest parts do not appear to have suffered attrition or injury of any kind.

Fragmentary Rocks.—The rocks composed of fragments and rounded water-worn pebbles afford us the strongest evidence of progressive destruction, deposition and consolidation.

Among the transition rocks we find, in general, for the first time, fragments both rounded and angular of all the previous rocks; sometimes these fragments are united by crystalline matter of a different nature, forming the paste or cement which holds them together; or the paste is composed of nearly or quite the same materials with the fragments, but in a state of much finer division, and at other times there is little interposed matter.

Many of the rocks of this class are most palpably fragmentary, the fragments being of all sizes, either scarcely visible to the naked eye, or several inches or feet in diameter.

Instances.—We have seen and carefully examined, in place, all the following instances of fragmentary rocks, namely:—The brecciated marble of the Potomac, employed in the public buildings at Washington; this is a remarkably firm rock, composed of angu-

lar and ovoidal pebbles, the latter of which have evidently received their shape from friction in water. The cement is a more minutely divided substance of the same kind; but calcareous matter is not exclusively the material either of the pebbles or of the cement.

The fragmentary rocks of Rhode Island, extending by Providence to Boston, and which are very conspicuous in Dorchester, Roxbury, Brooklyn, and other neighboring towns, are fine examples of early formations of this kind. They are very interesting five miles east of Newport, at a place called Purgatory, where a large mass of the rock is separated by the natural seams, that appear to have been produced by a subterranean heave. The seams run parallel for a great distance, cutting the pebbles in two, and thus the included mass has fallen out, having been undermined by the sea, whose waves, when impelled by storms, break and roar frightfully in this deep chasm.

The pebbles are here chiefly quartz; they are ovoidal in form and of every size, from that of a bird's egg to that of a barrel, and they lie generally with their transverse diameters parallel. They are frequently invested by numerous crystals of the magnetic oxide of iron, perhaps sublimed by the heat that elevated the strata.

The pebbles of the fragmentary rocks about Boston are very various in their composition, but are obviously the ruins chiefly of primary rocks. The pebbles, which there lie in the roads and fields, have proceeded from the disintegration of this puddingstone.

The great sandstone deposit of the valley of the Connecticut presents every variety in the size and form of the parts that have been broken up from previous rocks, transported, more or less rolled, and cemented into rock again.

In East Haven, near New Haven, the rocks often contain massy pebbles of granite, gneiss, mica slate and clay slate, and of the individual minerals of which they are composed. Water-worn pebbles are in some places as common in these rocks as on the sea shore: they form mighty strata, which have been tilted out of the horizontal position, into an inclination of 15 or 20 degrees from the horizon; their successive parallel ridges resemble the waves of the sea, and between them are the long-drawn troughs, extending with great regularity in the direction of the strata.

The Catskills, are conspicuous monuments of geological revolutions, for not only at the base, but at the summit, from two to four thousand feet above the level of the Hudson River, we find them composed extensively of fragmentary rocks, rounded and angular; their rude piles inform us, that the materials of which they are built were once loose and rolling about, in the waves of an early ocean, encountering friction and violence in their various modes of action, and it admits of not the smallest doubt that these mountains, after consolidation, have been raised from the depths of the sea into their present position—lifted doubtless with the continent of which they form a conspicuous feature.

Origin.—We must look for an adequate cause whence arose the mighty masses of ruins of every shape and variety, composing not merely accidental fragments, or here or there a stratum or a hill, but covering myriads of square miles, the foundation of countries, and rising occasionally even into high mountains.

Such are the effects and proofs of crystallization, as exhibited in the primary rocks, that the contrast afforded by the fragmentary piles, must appear very striking; and connected with their relative position, can leave no doubt on the mind, that they arose from a subsequent and totally different state of things.

What were the causes that broke up portions of the primary rocks and left their ruins the sport of the waves, destined in the progress of time, to be cemented again into firm masses?

Causes which appear very feeble in their action produce, by long continuance, results which we are sometimes inclined to attribute to more violent agents. Such are the wearing effects of the weather and the seasons, and of the vicissitudes of temperature, powers constantly in operation, and to these we can add the convulsions of earthquake, tempest, flood, and fire, by which our planet is still as it has ever been agitated. These causes would, in the course of ages, perform the work, great as the results may now appear.

The breaking up of primary and other rocks by ordinary causes, as well as by violent convulsions, and the transportation of their ruins, often to distant places; the frequently rounded form of the fragments, presenting pebbles of every size, from that of a pea, to that of a hen's egg, a human head, or a barrel—quartz being not

unfrequently the material; the reconsolidation of these masses into firm rocks—their stratification at first horizontal and then rising, at various angles of inclination; the alternation of such strata with slate and coal and other deposits, their extraneous contents of innumerable organized beings, and the elevation of the whole, sometimes hundreds or thousands of feet above the ocean level; all these facts leave not a doubt that the fragmentary rocks required much time for their formation, consolidation and elevation, and could never have been the work of a short period, or of a transient deluge. It is evident also, that some of the brecciated rocks were deposited before the granite mountains broke through them, tilted them up, and threw them into positions of high inclination, as may be seen in various places among the Alps.

Diluvial Deposits.—As regards the wreck and ruins with which the surface of our planet is every where covered; their extraordinary position, and to some extent their production, have been usually, but as is now thought too generally and exclusively, attributed to diluvial agency; to mighty floods and rushing torrents of water.

Diluvium is found every where. The almost universal deposits of rolled pebbles, and boulders of rocks, not only on the margin of the oceans, seas, lakes, and rivers; but their existence, often in enormous quantities, in situations quite removed from large waters; inland, imbedded in high banks, or scattered, occasionally in profusion, on the face of almost every region, and sometimes on the tops and declivities of mountains, as well as in the valleys between them; their entire difference, in many cases, from the rocks in the country where they lie—rounded masses, and pebbles of primary rocks, being deposited in secondary and tertiary regions, and vice versa; these, and a multitude of similar facts, are among the most interesting of geological occurrences. Curvilinear stones may possibly, in given instances, be formed by decomposition of the angular portions, and by various chemical agencies, aiding those of a mechanical nature; but pebbles present unquestionable evidence of having been brought to their rounded form by friction in water, aided by sand and gravel and by mutual collision, and they can scarcely be confounded with those produced in any other way.

The attrition of the common waters of the earth, within the limited period of our observation, aided by transient and occasional floods, or even by the deluge described in Genesis, would do very little towards producing so mighty a result; and we must assign the effects not only to our own times, but to an earlier and much more extended course of mechanical agencies, produced by agitated waters, through successive ages.

We must charge to moving waters the undulating appearance of stratified sand and gravel, often observed in every country, and very conspicuously in the plain of New Haven; in remarkable beauty and delicacy in many places in the valley of the Connecticut River, and especially at Mink Brook, a mile or two below Dartmouth College; exhibiting frequently a delicacy of flexion in the layers, which makes them appear as if they had, but a moment before, received their impulse and position from undulating currents, and as if they had copied the very eddies and gyrations of the wave.*

Indeed nothing in geology strikes the observer with more interest, than these beautiful arrangements in strata, of the beds of sand, gravel, clay, loam and pebbles.† A section of a bank of any of these deposits—or better still, an avulsion or fall, which leaves the stratification exposed, without being obscured by the rubbish, produced by digging, or by the sliding of loose sand—never fails to exhibit the effects of sedimentary deposition; sometimes horizontal—sometimes inclined at various angles, great or small—sometimes undulatory, and recording, in a language that cannot be misunderstood, the effects of subsiding water. The beds are not always arranged in the order of the magnitude of the parts. Sometimes coarser gravel, or even pebbles, will form a layer above fine sand, and then perhaps the order will be reversed, indicating that there were currents, and these, relenting and increasing alternately, as they were impelled probably by tides or storms, so that coarser or finer materials were transported and deposited, as the waters and currents were more or less agitated and rapid.

---

* These strata would perhaps be now arranged with the tertiary.

† For our present purpose it is immaterial whether these depositions be referred to tertiary deposits, or to those that are strictly diluvial.

Bowlder stones, consisting of fragments of primary rocks, probably from the regions north of the great lakes, are found abundantly on the secondary regions of Ohio, New York, and other states; the fragments of the primary Alps, on the Jura chain, the ruins of the Scandinavian Mountains on the secondary and diluvial plains of Prussia and Northern Germany, (the Baltic intervening,) and the fragments of the northern counties of England, cover the southern and middle regions.

In many cases bowlders and pebbles can be traced to their native beds, and frequently they are strangers to the regions where they are found.*

Deserts of sand, covering tracts more or less extensive, such as those in South Africa, in the Zahara, stretching in a vast belt, from the Atlantic ocean to the desert of Lybia; the sandy plains of Arabia, Germany, and Russia; the great desert at the foot of the Rocky Mountains, and all similar deposits, in situations where no obvious existing causes could leave them, are usually referred to diluvial agency. It is suggested however by Dr. MacCulloch, that the sands may in various cases have been derived from the decomposition of rocks in situ.

Diluvial Torrents—Lakes—Valleys.—That diluvial torrents, especially when aided by convulsions and by ice, have had sufficient power to roll even bowlder stones and disjointed columns† to great distances, or to precipitate them from their native ledges into the valleys, is sufficiently evident, from what we know of the energy of torrents in our own time.

Beds of sand, gravel, clay, loam, pebbles, and bowlders, compose the loose materials of every country, and they invariably exhibit the appearance of deposition from water, sometimes tranquil, sometimes more or less agitated.

---

* Erratic bowlders are rarely found in lower latitudes than about 40° in either hemisphere, and they become more abundant as the latitude increases, thus indicating transports by currents of floating ice, freighted with rocks, from the polar regions.—*Lyell's Elements, (p. 173,) quoting Darwin.*

† Such as the columns of trap, sometimes of enormous size, which are found scattered, up and down, through the great Connecticut valley, often at a great distance from their parent ridges. The most remarkable case in this range, is ten miles west of Hartford, on the Albany turnpike.—*See Tour to Quebec.*

Moving waters appear to have first transported, and then, in a state of comparative quietude, to have arranged these masses by sedimentary deposition.

The effects of diluvial devastation are in a considerable degree veiled, by the gradual depositions of sedimentary matter, during the decline of the velocity of the moving waters.

Granting that the crust of the earth has been covered by water, which has been in any way withdrawn, or that the land has been lifted from a state of submersion in an ocean, there must evidently have resulted a multitude of local lakes, determined in their form and position by the basin shape so often traced by contiguous hills and high grounds; in these, separate and independent deposits might have been going on for a length of time. Those lakes that had no permanent supply of water, would, of course, be exhausted by soakage and by evaporation: others would burst their barriers, or gradually wear them down, and during their escape, produce diluvial ravages; while those only would be perennial, which were fed by streams and springs.

Many valleys of denudation, as they are called by Prof. Buckland, were probably produced by diluvial action, aided by convulsions. Such valleys are conspicuously seen in the South of England, on the channel coast, where similar strata are found capping contiguous hills, projecting at their sides, and running beneath their foundations; a curve or hollow having been scooped out between, thus indicating the effects of great rushing torrents, preceded or attended perhaps by earthquakes that, more or less, broke up the superficial strata.*

Many valleys were doubtless produced in this manner; and others by great diversity of causes.

Extraneous Contents of the Diluvium.—In all countries, where curiosity and intelligence exist, single bones, and entire skeletons of the larger animals, often of extinct species, but chiefly of known genera, are found abundantly in the diluvium.

Whales, sharks, and other fishes; crocodiles, and other amphibia; the mastodon, the mammoth or extinct elephant, and other species of elephants, approaching to or quite like those of modern times;

---

* Reliquiæ Diluvianæ.

the rhinoceros, the hippopotamus; hyenas, tigers, deer, horses; various species of the bovine family, and a multitude more, are found in the diluvium, or in the tertiary, at a greater or less depth; and in all the variety of circumstances in which they may be supposed to have been buried, either by ordinary occurrences, or by a catastrophe such as a sudden and violent deluge.

It appears, from Dr. H. H. Hayden's Geological Essays, that under the diluvium of the Atlantic portion of the middle and southern states, there lie buried great quantities of the bones of whales, sharks, porpoises, mastodons, Asiatic elephants, and other large animals, along with numerous trees, sometimes retaining their fruit. Layers of marine mud are also found, deep in the diluvium, beneath the present low water mark.

There are also vast deposits of shells, and especially of a gigantic oyster, in many parts of the southern states. They are found, not only in digging for wells, but they form great beds in various places.*

Near Tours, in France, is a stratum of oyster shells twenty seven miles long and twenty feet thick.

But the collections in the southern states far exceed this. A stratum on the whole continuous, although mixed more or less, with the general diluvium and other materials of the country, has been traced from the Eutaw Springs, in South Carolina, to the Chickasaw country; six hundred miles in length, by ten, or from that to one hundred in breadth.†

There can be no doubt that many of the beds of oyster shells, which have been attributed to the aboriginal Indians of this country are diluviul or tertiary deposits.

The bones and skeletons of large animals, especially of the mastodon and mammoth, are found in wide dispersion, and in very remote countries, in both Americas, in Europe, and in Asia. In northern Asia, the tusks of the extinct elephant or mammoth are discovered in the banks of almost every river, and the ivory is found in such abundance, as to be a regular article of commerce. An enormous carcase of the northern or extinct Asiatic elephant, by the gradual thawing of the frozen bank in which it was imbedded,

* Many of the cases cited are doubtless in the tertiary.

† We suppose these to belong rather to the tertiary.

high above the water, fell down a few years since, and exhibited the flesh in full preservation; the long bristly hair and vast massy hide, requiring a large number of men to carry it, afforded proof irrefragable, of the existence of the animal in those rigorous climates, and of his sudden extinction, inhumation and congelation, with so little interval of time, that putrefaction had not commenced, and has not since taken place, during a succession of ages.

It has been a favorite view with the religious world, that the deluge of the Bible was the cause of the wide dispersion and sepulture of the extinct gigantic races, whose remains are found in diluvium in the various quarters of the world, and that whole races of animals were thus extinguished, and their bodies buried in the wreck of the planet. Such a scene of devastation was thought to be well fitted to produce these effects, as it was certainly ill adapted to the comparatively tranquil life and death of the successive generations of marine and aqueous animals, that peopled the earlier oceans.

A more extended and careful examination, and a more scrupulous weighing of evidence has, however, induced most geologists, including those who have the greatest reverence for the Scriptures, greatly to modify these opinions. While all agree that the extinction of races of animals, in various cases, by deluges, is not only possible but probable, it is admitted that a multitude of the animals whose remains are found, perished by ordinary events, by miring, by accidental drowning, by mutual warfare, by disease, by old age, and by the prowess of the hunter, while the natural and usual movement of the waters of the earth, aided by the accumulations of time, may have effected their sepulture.

That all lands have been elevated from beneath the waters, and that some parts of the world have been repeatedly submerged and raised is, on grounds strictly geological, believed by all geologists; nor can we hesitate to admit also that flowing if not rushing waters, have passed over the surface of all countries; hence such effects as are appropriate to a general deluge are noticed in every region. Shall we add to this roll the following facts, cited on credible authority? The skeleton of a whale lies on the top of the mountain Sandhorn, three thousand feet high, on the coast of the Northern Sea.

So late as June, 1824, the remains of a whale were found on the westernmost Stappen, a mountain in Finmarck, at an elevation of eight hundred feet above the ocean. The bones, reported to be vertebræ, were lost by shipwreck on their passage to England. Similar remains are said to exist also in North Fugeloe, another mountain in those regions.—*Penn.*

While it may be supposed that there is no cause, except a deluge, that could have conveyed the whales to those elevations, it may perhaps be admitted by some, that the rising of the land may have brought up the skeletons, as Mr. Lyell supposes that bowlder stones may have fallen from sea cliffs, and being rounded in the ocean, have been then lifted into daylight.

If the elevation of land from the deep be admitted—and the fact is unquestionable—then it follows of course, that when the bottom of the sea, with its varieties of surface, of plains, valleys, hills, and mountains, is raised above the water so as to become dry land, then every thing that was lying in the abyss must be brought into view, or within the reach of exploration, and in this manner most interesting disclosures may in future eras be made.

Contrast between Diluvial, and Tranquil Aqueous Agency.—The agency of water, whether fresh or salt, in sustaining, depositing, and burying organized bodies in solid rock, (except the effects of occasional convulsions,) was, evidently, tranquil and long continued; giving time for many generations of the same or of different races, and for all the alternations and successions of the strata with different organized bodies.

The occasional intervention of igneous irruption, whether submarine or subterrene, below, or among, or upon the strata of aqueous origin, only increases the necessity of time, and when these coincidences occur, they add to the evidence of grand geological cycles.

But diluvial agency is usually violent, sudden, and of short duration.

If the universal deluge recorded in Genesis, be taken as a type of diluvial action, and the time and the elevation stated in the history, as measured by existing mountains, be taken into the account, nothing could be more violent, destructive, and overwhelming; and certainly upon the face of the earth are every where

recorded in legible characters, the necessary physical effects of such a debacle.

It has entered but little into the views of any except geologists to discriminate between these two classes of effects. They are as wide apart as possible, and nothing in science is more unskilful or more unhappy than to confound them, as is constantly done by the unlearned in geology, who are intent on attributing all geological effects to the deluge.

The surface of our planet has, either at one period or many, been swept by violent, agitated torrents of water, which covered the earth every where with its own ruins, but probably cataclysms did not form any of the firm strata filled with organized remains.

Volcanoes.—Their probable causes have been already mentioned in our view of elementary action, and it is sufficient for our present purpose briefly to advert to volcanoes as striking physical features of the earth. Active volcanoes are well known; their causes are now, as they have ever been, in operation, and lava beds and currents are constantly forming in many countries, so that, in one region or another, the earth is never free from volcanic action cognizable by the senses. The products of volcanoes often bear, in their very texture and features, palpable marks of the agency of fire, and thus they inform us, in very intelligible language, that they are indeed ignigenous: even when these features are not distinctly legible, it often happens that the geographical and geological position of the masses does not permit us to entertain a doubt of their volcanic origin. Although they may form beds of solid rock, which have no appearance of scoriæ, cinders, glass, or gaseous inflation, except, perhaps, on their upper surfaces, we still observe their currents, and recognize their birth by fire. Volcanic currents overflow whatever lies in their way, and therefore we find them covering, occasionally, every geological formation, and every work of man.

The superincumbent mass is, therefore, of more recent origin than that upon which it lies. The evidence presented by the eruptions of active volcanoes, and the igneous formations which they produce, goes then to establish the truth of geological succession, but does not imply that its events are more ancient than the masses which are covered.

Extinct Volcanoes.—Formerly extinct volcanoes were vaguely referred to, but without decisive proof of their real igneous origin. Many uninstructed persons were formerly ready to find extinct volcanoes in conical hills, especially if they had a hollow on the summit; and porous stones, of whatever kind, were referred to a similar origin. It was a very captivating and sublime idea, that volcanic fire, still bursting forth, in many places, with destructive energy, had, in times long past, exerted agencies still more extensive—covering provinces with ruins, and operating even in the bed of the primeval oceans. Still the speculation was regarded as somewhat visionary till the middle of the last century, when the subject of extinct volcanoes began to be investigated with accuracy and skill.

It will be sufficient to name the so much disputed country of Auvergne, Velay, and Viverais, in France, which has been often examined by able geologists; and now no one visits that region without being convinced that it is of volcanic origin. This district lies upon the river Rhone, nearly in the angle formed by it with the Mediterranean, and covers a square area of forty or fifty leagues in diameter.

Craters, regularly formed, often entire, sometimes with the thin and scorified edge of the lip in fine preservation, and occasionally of vast dimensions; here, black, rugged and scathed with fire—there, overgrown with trees, and there, filled with water; dykes of solid rock cutting through the volcanic cones; currents of lava, lying where they flowed from the crater, or where they burst from the sides or foot of the ruptured mountain, extending many miles and many leagues, traceable directly to their source, winding along the gorges and the sinuosities of the valleys, now and then diverted from their course by rocks, hills, and other obstacles; sometimes damming up rivers, whose beds they have crossed or obstructed, and thus forming lakes of considerable dimensions; exhibiting all the varieties of lithoid lava, from that which is compact like rock, to that which is, in a greater or less degree, porous and vesicular; crowned or mixed with slag, scoriæ, pumice, olivine, and other products of known and active volcanoes; displaying frequently a structure, now spherical, ovoidal and concentric; now prismatic and columnar, and fronting

streams, and bounding valleys, with ranges of columns, equalling or rivalling the regularity of the basaltic colonnades of Fingal's Cave and the Giant's Causeway: such are a few of the most striking features of these countries, which are so affluent in proofs of igneous origin, that there is nothing needed but to select, carefully and judiciously, those facts which will be the most decisive, especially with respect to minds not familiar with geological subjects.

The volcanoes of the Auvergne, &c., are regarded as of different ages; some appear to have been active before the formation of the present valleys, and some since; where the currents of lava have been cut through, by those causes which formed the present valleys, they are then obviously older than the valleys, and where these currents have flowed into valleys, beds of rivers, &c., they are as evidently of a more recent date.

Although the formation of these volcanic regions was anterior to the records of history, still their epoch was evidently subsequent to the creation of organized beings, which are found imbedded in the volcanic tufa.

The recent researches of Humboldt, "have greatly extended our knowledge of the volcanic tracts of our globe; he has shown the whole country round the Caspian to be a vast district of this nature, a 'pays cratere,' exactly resembling, in its general outlines, the telescopic appearance of the moon; he has also pointed out another great seat of volcanic action, the chain of Thion Chou, south of the Altai, and running about lat. 42° N. and between 70° and 80° E. long. from London. This vast ignigenous district extends over two thousand five hundred square leagues, and being generally remote from every sea, it evinces that marine contiguity, although a common, is by no means an indispensable concomitant of volcanic action."*

For our purpose it is not necessary to go any farther into detail with respect to this class of rocks. All that is true of modern eruptions from active volcanoes, considered as proofs of succession in geological events, is true in the present case. Every thing was occasionally covered by the currents that issued from the an-

* Discourse of Prof. Conybeare on Geology, at Oxford University, 1832.

cient volcanoes, and there is no reason to doubt, that, as happens in connexion with modern volcanic convulsions, destructive earthquakes preceded and attended their eruptions.

Having already thrown out some suggestions with respect to the theory of volcanoes, we shall only remark with Conybeare, that "it is impossible to propose any probable theory of volcanic phenomena which does not, at the same time, embrace the entire structure of the globe, in all its generality."*

The truth of this remark is already realized, for, not only trap, porphyry, and pitchstone, but serpentine and soapstone, and even granite, are now universally admitted to be of igneous origin.

The intrusion of the igneous rocks among those that are superincumbent, producing dykes and veins, often much ramified and frequently metalliferous; the elevation and disruption of the upper strata; the confusion often induced among them; the chemical changes produced upon the contiguous masses, and the profuse and rich crystallization of many of the primary rocks, both in their own proper minerals and in foreign imbedded ones: all these afford decisive proofs of geological order, event, succession, and time sufficient for the phenomena.

Crystallization in Rocks.—No person in the least acquainted with the subject, hesitates to admit that crystallization implies a previous state of corpuscular freedom, either in fluidity, in fusion, in vapor, or at least in a state of softness or diminished cohesion. Although crystallization is not confined to any one geological period, it is eminently conspicuous in the primary rocks.

It presents to a practiced eye and an instructed mind, very decisive proofs that the particles have been in that state of *mobility* which left them at liberty to unite according to fixed laws; the heterogeneous masses being connected by chemical, and the homogeneous by mechanical attraction. Thus in feldspar, (if we include both its necessary and occasional constituents,) oxygen is an element in all the binary compounds that enter into its constitution; in the silica it is united to silicium; in the potassa to potassium; in the soda to sodium; in the lime to calcium, and in the usual contaminating oxide, to iron. Supposing these to be the ultimate elements of the mineral, the proximate principles

* Discourse at Oxford, 1832.

would be produced, first by their uniting, chemically, and in definite weights, to form these binary compounds; which would still farther unite, but still chemically, to form the integrant particles of the mineral, and these particles united mechanically by cohesion, would form the mineral itself.

The same reasoning may be applied to every variety of crystallized rocks and minerals. Limestone, consisting for its immediate principles, of lime, carbonic acid and water, contains, for its ultimate elements, according to the present state of our knowledge, calcium, carbon, hydrogen and oxygen; the latter principle being united with each of the former ones, so as to produce the lime, (oxygen and calcium,) the carbonic acid, (carbon and oxygen,) and the water, (oxygen and hydrogen.) If the limestone were a magnesian one, then we must add oxygen and magnesium, and so of other earths, as silica, or alumina, if they were present.

In our introductory remarks we have observed, that how far back, and how near to the isolated, independent state, we are to trace the elements, we cannot determine. Whether they were created in perfect freedom, or whether combined in pairs, and those pairs again united to form complex results, we can never know with certainty, and all our suggestions on this subject are necessarily hypothetical. But the principles are true, and the statements might easily be extended to the most complex rocks, and to all their imbedded minerals; but without going into all these details, we may reason both intelligibly and conclusively upon the act or process, which, according to physical laws, may have preceded the concretion of the materials of the primary rocks.

Suppose a previous state of chemical mobility by fire to have rendered it possible that the elements of granite should unite; a simultaneous formation of the different minerals must of course happen; the quartzy particles must find their fellows, those of feldspar and mica would do the same, and the three minerals, born at the same moment, might repose in the same cradle. In the same manner, their ornamental companions, (not essential to the rock, butoften studding it like gems set in royal robes)—the emeralds, the topazes, the garnets, the tourmalines, and other crystallized minerals, which sparkling in the bosom of the primary rocks declare a coeval birth, may have had a similar origin.

True it is, that creative power could call the rocks into being, without any arranging process in their parts, but no analogy countenances the truth of such a supposition, and neither moral nor physical reasons oblige us to admit so improbable a supposition.

Who has contemplated the stupendous garnets of Fahlun—the equally gigantic quartz and feldspar crystals of the Alps—the more delicate emeralds of Brazil and Ethiopia—the variously colored tourmalines of Chesterfield and Goshen, Mass., and of Paris in Maine—the idocrases of Vesuvius—the rubies and sapphires of Ceylon and other regions of India—the bubbles of air included with water and other fluids in quartz—the fibres of amianthus—the crystals of titanium—the filaments of native copper and silver shut up in the same mineral—the successive crystallizations of galena, sulphate of barytes, calcareous spar, quartz and fluor spar, especially of Derbyshire and Cumberland, often included in one group—the splendid amethystine and other geodes—little grottoes lined with polished and beautiful geometrical figures—who with a skilful eye and an enlightened mind has seen such things, the ornaments of our cabinets, and has doubted that they were as truly the products of crystallization as any of those of art which are formed in our laboratories, and that both result from the operation of the physical laws established by the Creator.

Crystallization is indeed not exclusively the attribute of primary regions, but in them it is eminently conspicuous; and if we find crystals in every geological age, we are thus furnished with proof that these agencies continued to operate, although with less frequency and energy, through all succeeding periods, and that they have not ceased even in our own times,* for mine-

* I have obtained crystals of calcareous spar, of sulphate of barytes, and of sulphate of lime, and some of them repeatedly, as accidental results in chemical processes: I have seen even quartz crystals form rapidly under my eye, and others have cited them as slowly produced with regularity and beauty from the fluoric solution of silex. Crystals of pyroxene, specular iron, titanium, and other minerals have been produced by volcanic and furnace heat; more than forty species of minerals have been observed in the slags of furnaces, and white pyroxene has been produced by the action of fire upon the constituents of this mineral, and after fusion, it has re-crystallized in the same form.—*Am. Jour. Vol.* 10, p. 190.

ral crystals are every moment forming around us from solution, from fusion, from gas and vapor, and from the unceasing energy of galvanic power.

Still we do not find in the upper secondary rocks, much less in the tertiary, the numerous and grand crystals that are common in the primary, and even to a degree in the transition and early secondary formations, nor do we expect to find grand crystal cavities, *fours a cristaux*, as they have been fancifully called by Patrin, except in the ancient mountains and in the veins and beds by which they are intersected.

No person who has been conversant with chemical effects can easily confound them with those of mere mechanical deposition. Take a piece of the most beautiful granite—its quartz is translucent, if not transparent; its feldspar is foliated in structure, presenting two regular cleavage planes united at definite angles; its mica is perfectly foliated, and splits into innumerable thin laminæ, each of which is transparent and has a high lustre, and this last property is common (sometimes in a less degree) to the quartz and the feldspar. Gneiss and mica slate and saccharoidal limestone are distinguished, in a greater or less degree, by similar characteristics. Now translucency, transparency, lustre, cleavage-planes, and regular structure, are known and established results of chemical deposition, and are never the effect of mechanical aggregation. Compare the above properties with those found in a piece of clay, and no person, however unskilled in physical characteristics, can possibly attribute them to a similar origin. The latter has as obviously sprung from mechanical as the former from chemical laws; mechanical suspension must have preceded the one, and solution, fusion, sublimation, or galvanic secretion the other.

Crystallization is the most exalted agency of the mineral kingdom, and it answers to organization in the animal and vegetable. It results in the production of regular solids, often of beautiful figures, bounded almost always by plane faces, which constitute the outline of beauty in the mineral world, as the curve line does in the organized kingdoms.—*Haüy.*

Proximate Causes of Crystallization in the Earth.—As crystallization by natural laws is constantly going on around us, so

we can at pleasure form crystals of many substances; in some cases, we produce those that never have been discovered in nature, and in others we can surpass them in size and beauty; nor is there any reason to doubt that we could always imitate natural crystals, provided we were acquainted with all the powers and circumstances which operated in the original crystallization of mineral bodies. The discovery of Mr. Crosse, by which galvanic power has been made efficient in producing various crystallized minerals and metallic bodies, affords us a precious light on this subject, and as the galvanic power resides within the earth we feel assured that in all ages it has proved an efficient agent in crystallization. In all the geological epochs after granite, there is decisive evidence of great mechanical changes, operating first on the primary rocks, to produce the materials for the derivative rocks, which are again worn and broken and their ruins are aggregated in rocks still more recent; all such formations exhibit unquestionable proofs of mechanical destruction and mechanical formation; in a word, of changes from the pristine state of the materials, greater than crystallization implies in relation to the constituent or integrant particles, which we may presume to have been originally created.

Werner supposed that the crust of the earth had been dissolved in water, but the solution theory, once almost universally prevalent, has now given way to the igneous, which not stopping with actual or extinct volcanoes, or with trap, porphyry, and pitchstone, has taken possession of the granite mountains and of the very center of the earth. Still, it is admitted generally by geologists that the ocean has for a long time occupied all countries; and it is now evident also, that ignition and fusion on a great scale have always existed in the earth; this is conceded even by those who do not believe in the fusion of the central nucleus. The deep internal fires of our planet have been the most energetic, as would appear from the admitted fusion of granite, and they appear to have been most extensive in the earliest periods. Both in ancient and modern times volcanic mountains and islands have risen from the bosom of the ocean, and volcanic islands are still existing where in former ages the sea raged uncontrolled. The submarine volcanoes also occasionally project smoke, flames, and red hot stones through

the ocean, thus informing us that water cannot always subdue fire, that even now, there are strata at the bottom of the sea where extreme ignition and extreme hydrostatic pressure operate conjointly upon the firm materials, and that both, aided by the principal chemical agents which we know to exist in the constitution of our globe, may unite to produce results of which our trifling experiments can give us but a feeble conception. An attempt, for instance, to dissolve granite by boiling it in water, is just as rational as the effort to melt it in a common fire; neither experiment can possibly succeed; but the former would not prove that granite was never dissolved, nor the latter that granite was never melted; because, the circumstances which may have operated in the interior of the earth are not under our control, and our experiments are therefore inconclusive. We can melt a little granite by the compound blowpipe, and could we command this heat on an extensive scale, we might melt the granite mountains.

We should accept with equal readiness the aid of fire or water, or other agents, as they may appear best adapted to explain the phenomena.

In volcanic countries, silica is certainly dissolved by hot alkaline water under great hydrostatic and steam pressure, and granite is as certainly fused in the intense heat of deep seated fire. There is the best reason to believe, that in the lavas not only granite but all rocks are occasionally melted. If this be true of the proper crystals of granite, it may be also true of the imbedded crystals which it contains, and therefore of all other crystals.

Those which contain much water of crystallization may present a serious difficulty, but perhaps pressure may have retained the water and as the parts of the mineral concreted, in cooling, the molecules of water may have taken their place in the regular solid. Still we can see no reason for excluding water and other dissolving agents, acting with intense energy, under vast pressure and at the heat of even high ignition, from playing a very important part in crystallization.

If we give granite to igneous fusion it is hardly possible to avoid admitting the conjoined action of water and fire on the crystallized slaty rocks that usually cover it; the rocks that are now called metamorphic by Mr. Lyell, because he supposes that their

materials may have been first deposited mechanically and then chemically crystallized by heat acting under vast pressure.

Nature and Application of the Argument.—It is we trust obvious that we have been occupied, not in the superfluous labor of giving a system, a work which is ably done by our author, but in selecting a few facts from the principal geological classes and epochs, to evince that our planet, before it was inhabited by man, was subjected to a long course of formation and arrangement, the object of which evidently was, to fit it for the reception, first of plants and animals, and finally of the human race. This is the sole object which we have had in view in our citations of geological facts, all of which go to prove that the world is not eternal. For in that remote period of which he who recorded the fact probably knew not the date:—*In the beginning* God created the heavens and the earth, and established the physical laws, the ordinances of heaven, by which the material world was to be governed.

The earliest condition of the surface of the planet appears to have been that of a dark abyss of waters of unknown depth and continuance, which repressed the deep seated forces of internal fires.

The structure of the crust affords decisive evidence of a long series of events, in relation both to the formation of rocks, and to the creation and succession of organized bodies, which exist in the strata and mountains in such astonishing quantities.

Succession and revolution are plainly recorded in the earth; and sacred history expressly states that the events involved both order and extent of time.

Geology cannot decide on the amount of years or ages, but it assures us that there was enough to cover all the events connected with the formation of the mineral masses, and with the succession of the generations of living beings, whose remains are found preserved in them.

It is obvious that ages must have passed while the various geological events, which are recorded in the structure of the earth, were happening, and particularly while the innumerable organic beings that had been created, lived, perpetuated their race, died, were entombed and preserved in the rocks, and this through a

vast succession of generations of an immense number of families, genera and species.

As already suggested, (page 510,) we will not inquire whether almighty power inserted plants and animals in mineral masses, and was thus exerted, without design or end, in working a long series of useless and therefore incredible miracles. Can any rational man believe, for example, that many genera of fishes, with vertebræ and fins, and therefore created to live in water, like those of the present day, were placed by mere sovereign power in the slates and other rocks beneath the coal and therefore (as these formations exist in England and supposing all to be present that belong above) nearly two miles below the present surface; or that the iguanodon, with his gigantic form, seventy to eighty feet in length, ten in height, and fifteen in girth, was created in the midst of consolidated sandstone, and placed down one or two thousand feet from the surface of the earth, in a rock composed of ruins and fragments, and containing fish, vegetables, shells, and rolled pebbles! With such persons we can sustain no discussion, since there is no common ground on which we can meet: we must leave them to their own reflections, for they cannot be influenced by reason and sound argument, and can, with or without evidence, believe any thing that accords with their prepossessions. And yet we have known such individuals—those who either deny the best established facts, or endeavor to avoid their effect by making the most absurd suppositions, inconsistent alike with the truths of science, and with candor and fair dealing in argument.

Persons there are, also, who endeavor to do away the argument derived from organic remains, by denying their reality. They affect to regard them, as a lusus naturæ, which phrase, if it has any meaning, would imply, that the relics are not real, but only bear an accidental resemblance to plants or animals. This resort is too ridiculous to deserve refutation, and no individual would hazard such an explanation, who had been in the slightest degree acquainted with fossils, those beautiful medals of past ages. They have been, by the operation of natural laws, laid by, and preserved in the solid strata of the earth, as authentic and imperishable monuments both of the progress of the mineral formations, and of the numerous creations of animals and plants that occupied the suc-

cessive surfaces of the planet before man was called into being; nor did the record cease to be enrolled when man appeared—it was, and is, and will be continued, as long as the earth shall exist.

The order of the physical events, discovered by geology, is substantially the same as that recorded by the sacred historian; that is, as far as the latter has gone, for it was evidently no part of his object to enter any farther into details than to state that the world was the work of God, and thus he was led to mention the principal divisions of natural things, as they were successively created. It is sufficient therefore that there is a general correspondence, which is indeed, in the great features, exceedingly striking, and deficient only in less important particulars not to be expected in so general a narrative, written chiefly for moral purposes; but it is in no respect contradictory to facts.

The Bible is not a book of physical science, and its allusions to physical subjects are necessarily adapted to common apprehensions. Still, the creation and the deluge, although they have a momentous moral bearing, were, *in their nature*, entirely physical operations. Why should any one refuse to attend to a history of these two stupendous events, merely because that history professes to have proceeded from the same author as the work itself; and why should we suppose that the brief notices of the great *physical* facts, connected with a *physical creation* and a *physical destruction*, are not correctly stated, in this earliest and most venerable of histories?

If all our discoveries regarding the surface and interior of the planet tend, when properly understood, to confirm the credibility of both these events, and to enable us to discriminate between the circumstances and evidence which belong to them respectively, what moral consideration can, in this case, forbid a happy application of the discoveries of science, and why should science refuse to lend its aid to the support of moral truth?

The question then recurs, how can the amount of time be found, consistently with the Mosaic history, for the order of the facts and of the history is the same. The solution of this difficulty has been attempted in the following modes.

1. *The present crust of the planet has been regularly formed between the first creation "in the beginning,"* and the commencement of the first day.*—It appears to be generally admitted by critics, that the period alluded to in the first verse of Genesis, "in the beginning," is not necessarily connected with the first day. It may therefore be regarded as standing by itself, and as it is not limited, it admits of any extension backward in time which the facts may require.†

Dr. Chalmers says: "Does Moses ever say, that when God created the heavens and the earth, he did more at the time alluded to than transform them out of previously existing materials? Or does he ever say, that there was not an interval of many ages betwixt the first act of creation, described in the first verse of the book of Genesis, and said to have been performed in the beginning, and those more detailed operations, the account of which commences at the second verse, and which are described to us as having been performed in so many days? Or, finally, does he ever make us understand, that the generations of man went further than to fix the antiquity of the species, and of consequence that they left the antiquity of the globe a free subject for the speculations of philosophers."—*Evid. Christ. Rev. in Ed. Encyc.*

By asserting that there was a beginning, it is declared that the world is not eternal, and the declaration that God made the heavens and the earth, is a bar equally against atheism and materialism. The world was, therefore, made *in time* by the omnipotent Creator.

The creation of the planet was no doubt instantaneous, as regards the materials, bnt the arrangement, at least of the crust, was gradual. As a subject either of moral or physical contemplation, we can say nothing better, than that it was the good pleasure of God not only that this world should be called into existence; but, that the arrangement by which it was to become a fit habitation for man, should be gradually progressive through many ages.

---

* "*Of old* hast thou laid the foundations of the earth, and the heavens are the work of thy hands."—Ps. cii: 25. "And thou, Lord, *in the beginning*, hast laid the foundations of the earth."—Heb. i: 10.

† "This statement appears to be entirely distinct from all that follows."—*W. M. Higgins, F. G. S.; the Mosaic and Mineral Geologies: London*, 1833.

This is in strict analogy with the regular course of things in the physical, moral and intellectual world. Every thing, except God, has a beginning, and every thing else is progressive. The human mind and our bodily powers, the growth of the animal and vegetable races, the seasons, seed time and harvest, science and arts, wealth, civilization, national power and character, and a thousand things more, evince that progression is stamped upon every thing, and that nothing reaches its perfection by a single leap. The gradual preparation of this planet for its ultimate destination, presents therefore no anomaly, and need not excite our surprise.

It is of no importance to us, whether our home was in a course of preparation during days or ages, for the moral dispensations of God towards our world could not begin until the creation of man.

The abyss of waters which existed before the emergence of the land, which preceded the creation of man, and continued for an unknown period of time, is just such a state of things, in coincidence with the operation of internal fire, as is demanded for the formation of the central rocks, and for their elevation, as far as facts may justify us in supposing that it took place before the formation of the derivative rocks, and of those containing organic remains.

The supposition now before us is equally consistent with both igneous and aqueous action; and indeed it would be impossible to account for the appearance of things without the conjoined agency of internal fire, and of an incumbent ocean; the latter repressing the expansive and explosive power of the former, causing its heat greatly to accumulate, even to the fusion of the most refractory materials; preventing the escape of gaseous matter, as for instance of carbonic acid gas from the limestones, and by its pressure and slow cooling, from the small conducting power of water, preventing melted rocks from assuming the appearance of volcanic cinders, slags, scoriæ, and other inflated masses.

The incumbent ocean is therefore indispensable, equally so with the agency of internal fire, to the correct deductions of the theoretical geologist.

With these views, then, the historical record happily agrees, and geology coincides with the sacred history.

During the period when this dark abyss of waters prevailed, the earth was without form, and void, or better, as Hebricians say—" the earth was invisible and unfurnished;" we may presume that then the early operations of geological formation and arrangement began, by producing the fundamental rocks, and thus providing materials for all the derivative strata, which, in the course of their consolidation, were destined to embosom such an endless diversity of extraneous contents.

This theory is satisfactory as far as it goes: it fairly recognizes and encounters the real difficulty in the case, and it would be quite sufficient to reconcile geology and the Mosaic history, as usually understood, did not the latter assign particular events to each of the successive periods called days; the most important of these events are, the first emergence of the mountains, and the creation of organized and living beings. It seems necessary therefore to embrace the days in the series of geological periods; and the difficulties of our subject will not be removed, unless we can show that there is time enough included in those periods called days, to cover the organic creation, and the formation of the rocks, in which the remains of these bodies are contained.

2. *The present crust was formed from the ruins and fragments of an earlier world, re-arranged and set in order during the six days of the creation.*—This explanation has been given by men of powerful minds, both theologians and geologists—men strongly impressed with the overwhelming evidence which the earth presents of innumerable events, and of progressive development through successive ages. It therefore honestly meets the difficulty, and fully grants the necessity of allowing sufficient time for the series of geological formations. This theory assigns the crystallization and consolidation of the primary rocks to a period of indefinite geological antiquity, and it also admits that they have undergone more recent modifications, particularly in being upheaved by subterranean force, which elevated not only themselves but the superincumbent strata.

The hypothesis has great merit, inasmuch as it admits, in the long gone-by ages, of just such events and successions as geology has proved to have taken place; but it demands general catastrophes, which do not appear to have happened, and it implies a recon-

struction of the crust of the planet entirely out of its own ruins, a supposition which is inconsistent with the state of facts. It is therefore unsatisfactory, because it does not provide at all for the regular successions of entombed animal and vegetable races, and for the progressive consolidation, often in long continued tranquillity, of the strata which are formed around the organic bodies, and also for the numerous alternations and repetitions of these strata, frequently, as in the coal fields, in a regular order. All this demands time, and seasons of protracted repose, interrupted indeed by occasional elevations, subsidences, and other violent movements. In order that this solution may prove satisfactory, it is necessary that the earth should really be what it actually is not, a confused pile of ruins, not only of loose fragments, such as are now found on its surface, but they must be consolidated, to form the mountains and the strata. Ruins, the mountains and strata do indeed in many places contain, but they form only a portion of a vast structure, in which ruins have no part.

The earth is unlike Memphis, Thebes, Persepolis, Babylon, Balbec or Palmyra, which present merely confused and mutilated masses of colossal and beautiful architecture, answering no purpose except to gratify curiosity, and to awaken a sublime and pathetic moral feeling; it is rather like modern Rome, replete indeed with the ruins of the ancient city, in part rearranged for purposes of utility and ornament, but also covered by the regular and perfect constructions of subsequent centuries.

The period is not far distant, when all thinking and reasonable men who make themselves acquainted with the structure of the earth, will come to the conclusion that the formation and arrangement of the crust, as we now see it, must have occupied many ages. This is already the conviction of all geologists, and of many who are not so by their pursuits; and nothing can prevent its becoming universal but ignorance of the facts, or a blind or perverse rejection of them in opposition equally to sound science and common sense. It is now generally admitted that the beginning was in remote antiquity, at a period whose date is unknown; and we are at liberty in consistency with sacred history to assume as much time anterior to the first day, as the events recorded in the structure of the earth may require. This appears at first

view to remove the difficulties, as they are supposed to exist between geology and revelation, and therefore this solution has been eagerly adopted by those who receive equally the truth of revelation as recorded in the Bible, and the truths of nature as registered in the earth. This extension of time may answer sufficiently for the primary rocks, and for those composed of fragments and ruins, so far as they do not contain organic remains or contain them accidentally. It is true, however, that among the fragmentary and brecciated rocks there are those that contain ruins charged with the remains of animals and plants; pieces of limestone, for example, enclosing corals, shells, or crinoidea, are found as parts of calcareous breccias, and in the same manner, plants embraced in argillaceous iron, or in slates and sandstones, may enter into the puddingstones and breccias, and it would be true of such rocks that they are formed from the ruins, if not of a previous world, at least of an earlier state of this world. But it must be observed, that by the supposition the organic remains now alluded to are not in the situation in which they were originally enclosed.

We will illustrate this by examples. Suppose a country occupied by the encrinal and coralline limestone. The rocks exhibit those beautiful forms either as they grew in the ocean, with all their exuberant and curious joints and branches standing upon their proper columns or stems and gently wrapped in the calcareous carbonate as it concreted around them; or perhaps they were fallen upon the floor of that early ocean, and their members perchance scattered around, but in the end they were equally enclosed in the delicate pabulum which was to preserve them without father alteration to distant ages.

Suppose also the fossils of the chalk formation—the echini with or without their spines, the alcyonia and sponges, the innumerable testacea, the vertebrated fishes, and, as we are now instructed, myriads of microscopic corallines and shell fish; let these and the other fossils of this chalk series be imagined as living in their native seas at the time when they were so exquisitely folded in their white chalky mantle as to insure the perfect preservation of their delicate forms, often with their minutest processes, spines, or other frail parts uninjured; still farther, let the flint, dissolved

perhaps in thermal alkaline waters, thrown up and issuing from the bottom of the chalk, now seek the organic forms and convert many of them into its own substance, but copying their organization so as to present silicified sponges, echini, alcyonia, &c.

Now these are instances of geological formations which, in such or in some other analogous modes, have certainly taken place, and innumerable repetitions of similar events have occurred from the time of the earliest organized beings down through successive ages, and are still going on. No one will however contend that these things are to be referred to the ruins of a former world; they are regular formations, and the animals and plants that may have been enclosed in the forming rocks have had no previous existence; where they are found petrified there they were born, and there they were interred in their stony tombs. Should any of these rocks, still retaining the enclosed organic bodies, be broken up into fragments, and should these fragments become united so as to form a breccia or conglomerate, this might with some propriety be called a formation from the ruins of a former world, or at least of an earlier stage of the present.

Regular and extensive formations, which enclose organized beings in immense numbers and in high preservation, must have demanded great time, prevailing tranquillity, and all the circumstances necessary both to sustain organic beings and to furnish the pabulum by which they were to be enclosed. The astonishing diversity of petrified and fossilized forms, found in strata of different kinds, of wide geographical extent, and in many instances of vast thickness, with their distinct and sometimes sudden alternations, successions, interventions and repetitions, demonstrate that physical laws of great energy reigned and produced their proper effects through vast periods of time.

It does not militate against the argument, that there were occasional convulsions, lacerating and dispersing in ruins portions of the fair fabrics that had been raised; or that less violent operations, carried on from age to age, tended more slowly but not less surely to the same result; the intercalated or concomitant processes of destruction served only to prove that there previously existed solid structures which the tooth of time or the crash of catastrophes had invaded, and therefore the regular mineral formations, the

entombed organized bodies, and the partial demolitions are thus linked into a harmonious system, furnishing a true geological chronometer and an authentic chronicle of physical events.

Now if the long range of time included between the beginning and the first day recorded in the Genesis is to cover not only the period in which those rocks were formed, that preceded the dawn of life, but also those that include organized beings and the formations composed of fragments, then it is obvious that the Mosaic history contains no notice of these events, *as belonging to that epoch.* But if it is still contended that the events really belonged to that period, although they are passed over in silence by the historian, and that six common days were allotted to rearrange and fit up the ruins of this ancient world, not only of rocks, but of animals and plants, so as to prepare the earth for the reception of the human race, then we feel justified in saying, that upon this supposition, the furniture of our present world could not possibly be what it now is, nor by any operation of physical laws could the arrangements be effected in so brief a period of time. The design would be most inappropriate, the appearances widely different from what we behold, and the work, except as a miracle, impossible. No supposition consistent alike with the work and the history will meet the exigencies of the case but a progress in the mineral formations coincident with the periods called days, in which life, in both organic kingdoms, is first announced in the Genesis, as the result of creative power.

Some eminent geologists, with whom reverence for the Scriptures and reverence for natural truth are only different modes of the same religious sentiment, both having for their basis veneration for the all-wise and benificent Creator, and proposing for their object, the promotion of confidence in him, and of obedience to his laws, have adopted this, as it appears to me, imperfect, if not inconsistent solution of the geological difficulties. As regards the coincidence of mineral formations with organic beings, it is just such a solution as would be satisfactory, were there no divisions of time in the Mosaic narrative, and nothing more announced in it than the order of events as actually narrated, the whole range between *the beginning* and the creation of man being left unembarrassed by the limitation of days, and perfectly free to be appropri-

ated in ample eras, as the events may seem to require. As the earth is really constituted, it will however answer no valuable purpose to imagine the collected ruins of a former world, brought together, to be remodelled; as the mariner who has survived the tempest, refits, with broken spars and sails, his wrecked and ruined ship. If the ruins and fragments of the present world are to be regarded as mere materials which are again to be concocted; in part dissolved or melted, and elaborately and skilfully wought over anew, to produce our present world, then this is equivalent to a new creation, and thus we introduce a double operation by almighty power, when one is quite sufficient, and after all, we leave our difficulties where we found them, without solution and without mitigation. This we must conclude is far from the truth, and our convictions are confirmed by surveying, with Mr. Lyell, the causes that are still in full operation, the geological events that are now in progress, and the effects that are proceeding without impediment or delay, and we thus discover, that since the creation, as regards geological causes, except their varying if not diminished intensity of action, all things remain as they were; no new code of physical laws has been enacted; while the beginning was with God, the continuation of events is with us, and a distant posterity may not witness their termination.

3. *It has been supposed that the succession of geological events may have happened in the first ages of the world, after the creation of man, and before the general deluge.*—This supposition is wholly irreconcilable with facts. The universal prevalence of the waters, rendered it indispensable that the first geological movement should elevate some portion of the land above the ocean. The great series of geological events by which the continents and islands were raised, was incompatible with the residence of man upon the earth: they precluded even the existence of terrestrial quadrupeds, which both geology and the scripture history assign to a late period in the order of things, the same period in the close of which man himself first appears; these movements were, until the period immediately preceding, hostile to the welfare of any beings that required more land than amphibious reptiles; and the vast deposits of fossilized and of crystallized rocks that preceded the era of reptiles, demanded an alternate and con-

comitant prevalence of water on the surface, and of fire beneath, which were ill adapted to produce and insure the quiet and firm state of the surface, such as we see it now. Although the great agents are still in operation, fire, water, storms, volcanoes, earthquakes, &c., their ultimate effects, if not mitigated in force, are spread through such a range of time, that human life is too limited to cover an extensive cycle of geological changes; the entire period since man was created is, in comparison with geological eras, but a brief space, and does not begin to bear any proportion to eternity. We have therefore, no reason to suppose that the earth has undergone any such changes, as to affect materially the integrity of its entire crust, since man appeared in the world.

It is true that events are in progress by which a series of fragmentary and fossilized if not of crystallized rocks is forming anew, and they may in time be elevated above the waters of the existing seas, while fresh-water deposits may in turn be drained; this world may last so long, that new continents may arise, where there is now a wild waste of waters, and far more ample space of redeemed land may be provided for the human family, without materially abridging the great highway of nations over the seas. There is no intimation in Sacred History, that any such events happened between the creation and the deluge, and it is obvious that the sparse population of the antediluvian world did not require more territory, especially when the existing races, with the exception of a few individuals, were soon to be consigned to the bosom of the deep, and all the continents and islands when again redeemed from water, were about to be given, in full dominion, to a single family. Although but one fourth part of the land of our world is, to this hour, reclaimed from the ocean, the population of the human family is far from occupying it all. Few countries are as yet peopled to the extent of their means of support, and it will require ages of peace and pure morals and effective industry, before more room will be demanded. We cannot therefore suppose, that a new continent would be elevated, until there should be a necessity for its appearance, and as nothing in sacred or profane history or in the structure of the earth intimates that such an event has happened, we feel quite certain that the great geological arrangements were accomplished before the human era.

4. *It has been supposed that a general deluge will account for all geological events.*—In the progress of the preceding remarks we have already had occasion to express a decided opinion on this subject, and it now remains only to sum up the argument.

This view is entirely inadmissible, except as to those superficial ruins which are commonly spoken of as diluvial. In using this term, geologists do not intend to imply, that these ruins are, of course, attributable to the deluge of the Scriptures.

In geology, a deluge is a rise and overflow of water. It has no exact limit in time, altitude or violence. A rain, a snow thaw, an outburst of a lake, a tide, a gale, or a whirlwind, may produce an overflow, but it is not usual to call the event a deluge unless the elevation has been both sudden and considerable. Were the barrier which forms the falls of Niagara to be suddenly ruptured, Lower Canada, New England and New York would be deluged; but the remarkable accumulation of water in the late seasons in the great lakes, in consequence of which they overflowed many buildings and many square miles of territory was not called a deluge.

The facts revealed by geology demand many partial deluges, and they are admitted by all geologists, with greater or less extent, to account for the transport and deposition of those things which water alone, or water aided by ice could convey. It is necessary also to suppose, that both fresh and salt water, either by their rising or by the subsidence of land, have alternately prevailed and retired, after continuing an indefinite period; sufficiently long, however, to give time for the various animals and plants, marine, littoral, pelagian, fluviatile, or lacustrine, which we find in successive strata, to be deposited and entombed. Igneous action, giving rise, in its vicissitudes, to subterranean expansion and shrinking, heaving and collapses, was the probable cause of these alternate movements.

Our concern, however, in the discussion under this head, is not with those regular formations which demand long continued energy of physical powers, and corresponding time to produce the effects; but it is with the general deluge, described in the book of Genesis, because we are writing for the sake of those who believe in the genuineness and authenticity of that history.

From the whole course of our argument, it is obvious, that the regular geological formations cannot be ascribed to that short and transient catastrophe. Its genuine effects are exactly those which all geologists ascribe to diluvial action; namely, the transportation of the loose ruins of mineral masses, and of the organic world, which are found strewed every where over the surface of the earth, or buried in its diluvium.

Professor Buckland, in his Reliquiæ Diluvianæ, has most ably illustrated the nature and effects of diluvial action; and it is obvious, that the former practice of attributing the organized remains found in the solid strata of the earth to this catastrophe, is founded entirely in an imperfect acquaintance with the subject, and that no man, who had studied geology thoroughly, would, at the present period, fall into such an error.

As the impression has gone abroad that Professor Buckland has deserted the opinions which he formerly maintained, we give him an opportunity to speak for himself. "The evidence (says he) which I have collected in my Reliquiæ Diluvianæ, 1823, shows, that one of the last great physical events that have effected the surface of our globe was a violent inundation, which overwhelmed a great part of the northern hemisphere, and that this event was followed by the sudden disappearance of a large number of the species of terrestrial quadrupeds which had inhabited these regions in the period immediately preceding it. I also ventured to apply the name *Diluvial*, to the superficial beds of gravel, clay and sand, which appear to have been produced by this great irruption of water.

"The description of the facts that form the evidence presented in this volume, is kept distinct from the question of the identity of the event attested by them with any deluge recorded in history. Discoveries which have been made since the publication of this work, show, that many of the animals therein described, existed during more than one geological period preceding the catastrophe by which they were extirpated. Hence it seems more probable that the event in question was the last of the many geological revolutions that have been produced by violent irruptions of water, rather than the comparatively tranquil inundation described in the inspired narrative.

"It has been justly argued, against the attempt to identify these two great historical and natural phenomena, that as the rise and fall of the waters of the Mosaic deluge are described to have been gradual and of short duration, they would have produced comparatively little change on the surface of the country they overflowed. The large preponderance of extinct species among the animals we find in caves, and in superficial deposits of diluvium, and the non-discovery of human bones along with them, afford other strong reasons for referring these species to a period anterior to the creation of man. This important point, however, cannot be considered as completely settled, till more detailed investigations of the newest members of the Pliocene, and of the diluvial and alluvial formations, shall have taken place."*

It appears then, that there is no other change in Prof. Buckland's views than what is common to the geological world, viz. that amidst the vast exuberance of diluvial remains, it is impossible to appropriate to the general deluge, those that belong to it, rather than to more local debacles, and to those of a different era.

It is not to be supposed that all deposits of gravel, sand, pebbles, &c. are attributable to the deluge of the Scriptures, for it is beyond our power to identify the particular piles and scattered ruins. It is sufficient to say, that as the earth bears every where, marks of diluvial action, and is in every country strewed with diluvial ruins, each observer will, for himself, assign to local deluges, or to a general debacle, as great a portion of the effects as may in his view belong to each. Scepticism cannot nullify or set aside the evidence, while the most reverent mind need not desire it to be more ample, nor is he who attributes diluvial remains, in many instances, to other diluvial events, to be censured, or regarded as an enemy to religious truth.

To those who would assign to the agency of a general deluge the vast work of depositing the immense consolidated geological formations, with all their varied stores of animals, and plants, and fragments, and diversified successions, we can only repeat the opinion already expressed, that such effects, from such a cause,

---

* Bridgewater Treatise, 2d Lond. edit., p. 93, note.

are physically impossible, especially within the limits of time and under the circumstances assigned in the Mosaic account. It is not necessary to go again into the induction of particulars.

We are however still of the opinion, that the actual disposition and arrangement of no small portion of the loose materials is to be attributed mainly to a diluvial ocean—no other probable cause being capable of reaching the regions remote from, and elevated above the present great waters of the globe, while the outline, and in many instances the mass of these deposits, must have been often disturbed by subsequent events.

The arrangement of the loose materials, on shores and in outlets, and in regions occasionally flooded, is to be referred to agencies now in operation.

It is also true, that water-worn pebbles are produced at the present time. No one who, on the sea shore, has observed the incessant lashing of the waves, and has listened to the hollow hum of the stones and pebbles rubbing against each other, with ceaseless friction, can doubt, that rounded, water-worn pebbles, are now every moment forming ; and were they found no where else, except on the shores, and in moving waters, there would generally be no difficulty in assigning their origin to this cause. But rounded stones, water-worn pebbles, and bowlders, are found in every country, on the surface and in the soil, and in regions the most remote from the ocean. This of course proves the universal prevalence, sooner or later, at once or successively, of agitated waters.

Why not, says an inquirer, attribute the rounding, as well as the position of the inland water-worn stones to the *diluvial* ocean? The obvious answer is, that the time allotted to the deluge described in Genesis is too short for the process of grinding down hard stones, which would necessarily occupy a very long period. A deluge attended by rapid currents and by floating ice could transport immense masses of these ruins, and deposit them where, to a great extent, we now find them ; but it was not possible that it could, in so limited a period, have effected much, in abrading the angular fragments of quartz, topaz,* and other hard stones,

* Found on a beach in New Holland. We have a topaz pebble from these shores which is perfectly ovoidal.

into ovoidal and globular pebbles and bowlders. That effect appears to have been, principally, the work of the earlier oceans.

The form of the loose materials that cover the rocks, more or less, in every country, is attributable chiefly to the wearing effects of agents, operating, *in all time*, to produce disintegration and decomposition; their present position may, in many cases, be fairly attributed to diluvial agency.

An ingenious author, Mr. Penn, convinced that the deluge could not account for the geological successions, has supposed them to be formed in the ocean, between the creation of man and the deluge, at which time the then existing land was, as he thinks, sunk, and the bed of the ocean raised, to form our present continents, bringing up, of course, all the marine deposits of sixteen centuries.

It is not necessary to discuss this theory. It is disproved by the discovery in caverns, and in the loose wreck, on the surface of the ground, of immense deposits of the bones of terrestrial animals, which have not, within the limits of human knowledge, lived in those countries where they are now found, and many of which could not exist in the present climates of those regions; for instance, the tropical animals, elephants, tigers, hyenas, hippopotami, rhinoceros, &c., are found now abundantly in the diluvium of England, and consequently England was dry land before the deluge that buried these remains, and therefore the existing continents have not been raised from the ocean since the creation of terrestrial quadrupeds, unless they were submersed after that epoch and then raised again. Of this there is not only no proof but the opposite is proved, because the diluvium is not covered by marine strata. Nor is it possible that the drowned quadrupeds of tropical regions should, by drifting, have reached England, and other countries still farther north, without decomposition and falling to pieces.

The coal beds also present indubitable proofs of having been formed from terrestrial vegetables, and therefore the regions where they are could not have been submarine, although the occurrence in coal-fields of some marine shells or plants may prove, that at the coal period there were islands and estuaries, where the sea had at least occasional access. Had the continents been again submersed and the bottom of the sea raised, after the creation of man,

we should find in the surface of the present crust, nothing but marine remains, which is contrary to the fact.

The existence of scratches and furrows* upon many rocks, (probably upon all when the diluvium is first removed from them,) appears to prove, that they have been subjected to movements of heavy bodies passing over them, either rolling down inclined surfaces, or forced along by floods, or pushed by glaciers, or dragged by moving ice, in which stones and rocks are very often frozen. The direction of these scratches on this continent, as well as in Europe, is such as to give the idea of a current or irruption from the north.

If the general deluge were a gentle movement, as Dr. Buckland now supposes, it could, as he justly observes, have produced very little alteration on the surface of the earth. If violent and rapid, then the effects would not have been forming, but destroying.

This is not the place to discuss the question of its literal universality. Many theologians have supposed that it was no farther universal than to accomplish its great object, the destruction of the existing races, except the reserved few. If it were strictly universal, and the highest mountains now known were literally covered to a considerable depth, it will be found that its rise must have been fearfully rapid, far transcending the most violent tides and bores with which we are acquainted, and that it would then be well adapted to harrow up the surface of the ground, and to transport and disperse its ruins, far and wide, over distant countries.

Upon either view, however, the deluge could never have produced the regular formations of the crust of the earth, and therefore, as regards this question, we may dismiss it from our contemplations.

We conclude this head by observing, that the remains of the human family, if buried in the diluvium of that period, may, in most instances, have been covered too deep for discovery, or have been swept into the sea; or if found in any instances, it is not probable that they would be distinguished from

---

* See an interesting paper by Mr. T. A. Conrad on the subject of the transfer of bowlders, &c. in the Am. Jour., Vol. xxxv, p. 237. Also an admirable memoir by Prof. Agassiz on glaciers, moraines, and erratic blocks.—*Jameson's Edinb. Jour.*, Vol. xxiv, p. 364.

bones buried in any other way, especially in countries like those which were then the principal seats of the human population; countries in which there has been since, no enlightened curiosity to prompt an intelligent research. We are not, at present, concerned to remove sceptical objections to the Scripture account of the deluge; we take it for granted that it is true, but the friends of the Bible sometimes suggest a question with respect to the inhumed human bones of that period, and this difficulty we wish to remove.

5. *The divisions of time called days in the Genesis are not necessarily restricted to twenty four hours, but may be understood to be periods of indefinite length.*—This view was supported, a few years since, by that eminent geologist, Professor Jameson, of the University of Edinburgh, in a comment upon the lectures of the illustrious Cuvier. We quoted the observations of Prof. Jameson,* in discussing the subject, in connexion with our edition of Mr. Bakewell's Geology, in 1833, and we shall make use of some of them on the present occasion. Cuvier remarks:—

" The books of Moses show us, that he had very perfect ideas respecting several of the highest questions of natural philosophy. His cosmogony especially, considered in a purely scientific view, is extremely remarkable, inasmuch as the order which it assigns to the different epochs of creation, is precisely the same as that which has been deduced from geological considerations."

" This, then, is the issue, in the opinion of Baron Cuvier, of that science, which has been held by many persons to teach conclusions at variance with the Book of Genesis,—when at last more matured by a series of careful observations and legitimate induction, it teaches us precisely what Moses had taught more than three thousand years ago."

We have already remarked, that the coincidences in the Mosaic account of the creation with the truths of geology, are the more valuable, because they are merely incidental to the main object of the history, which was to show that the world had a beginning, and was not eternal, to vindicate the claims of the Creator, as its author and governor, to point out the original state of the globe, and its progress towards a habitable condition, by the emergence

* Am. Jour. Vol. xxv, p. 26.

of the land,—to indicate the commencement of life, the order in which the principal classes of animated beings first appeared, and the final redemption of so much of it from the waters as was necessary to prepare it for man, whose creation consummated these astonishing displays of almighty power. Perhaps the claims to a perfect coincidence between geology and the sacred history, have been sometimes made in terms rather too unqualified. It is sufficient that there is a perfect coincidence in the great points, and inconsistency in nothing. A want of agreement has been stated as regards the priority of the animals of the transition rocks, in as much as they are found in deeper strata than the vegetation of the great coal period, whereas the vegetables are first named in the Mosaic account, and the earliest fossilized animals, actually found, are not mentioned at all. In regard to the vegetables, there is good reason to believe that they were at least as early as any animals; vegetables are found, more or less, through the whole transition series, in which the trilobites, orthoceræ, encrinites, corallines and mollusca, first appear; and we may probably regard plumbago as the result of vegetable matter, so perfectly carbonized as to have entirely expelled all the gases, and to have destroyed the traces of vegetable structure,—an opinion which is entertained by many geologists. Upon this view, vegetables will take the highest rank in organic antiquity, since plumbago, and even anthracite, are found in some of the slaty rocks of the granite family, anterior to the first appearance of any animals.

With respect to the silence of the history as to the very first animals, it may be said, that a brief narrative concerning the stupendous work of the creation, comprised within the limits of a single page, could not be expected to contain the minute details of natural history, and less important families would therefore naturally be omitted. Where in the history, is there mention made of infusorial animalculæ, any more than of the animals of the transition rocks? But as we cannot dispute the existence of these beings, both fossil and recent, there can be no doubt that their originals were really created. If in every other particular, this surprising history is consistent almost with the letter of the facts, and for so general a sketch, remarkably complete, it may well excite our admiration and gratitude. Professor Jameson proceeds:—

"The first chapter of Genesis is written in a pure Hebrew. This was the language spoken, and afterwards extensively written, by the people whom Moses conducted to Palestine from the land of Goshen. That it differed greatly from the language of the Egyptians, we have full proof in the Coptic remains of the latter, in the Egyptian proper names preserved in the Hebrew writings, and also in the circumstance that Joseph, when pretending to be an Egyptian, conversed with his brethren by means of an interpreter. Yet in the chapter in question, we find no foreign terms, no appearance of its being translated from any other tongue; but, on the contrary, it bears every internal mark of being purely original, for the style is condensed and idiomatical in the very highest degree. Had Moses derived his science from Egypt, either by oral communication or the study of Egyptian writings, it is inconceivable that some of his terms, or the style of his composition, should not, in some point or other, betray the plagiary or copyist.

"But the conjecture that Moses borrowed his cosmogony from the Egytians, must rest, moreover, on a supposition that the order which he assigns for the different epochs of creation, had been determined by a course of observation and induction, and the correct application of many other highly perfected sciences to the illustration of the subject, equal at least in their accuracy and philosophical precision, to those by which our present geological knowledge has been obtained. Nothing less than this can account for Moses' teaching us precisely what the modern geology teaches, if we allow his knowledge to be merely human. How comes it to pass, then, that while he has given us the perfect and satisfactory results, he has been enabled so totally to exclude from his record every trace of the steps by which they were obtained? The supposition of such perfection of geological knowledge in ancient Egypt, implies a long series of observation by many individuals, having the same object in view. It implies of necessity, also, the invention and use of many defined terms of science, without which there could have been no mutual understanding among the different observers, and of course no progress in their pursuit. These terms have all totally disappeared in the hands of Moses. He translated, with precision, the whole science of geology into

the language of shepherds and husbandmen, leaving no trace whatever of any one of its peculiar terms, any more than of the curious steps in its progress.

"But there is a phenomenon in his record still more unaccountable, upon any supposition that his science is merely human. His geology, acknowledged by the highest authority in this age of scientific improvement, to be thus accurate, dwindles down in his hands to be a merely incidental appendage of the most rational and sublime theology. This latter he did not learn in Egypt, for it was in the possession of his ancestors while they were yet inhabitants of Canaan.

"Shall we then conjecture, that Moses borrowed theology from the Hebrews on the one hand, and geological science from the Egyptians on the other, to compound out of them that brief, but unique and perfect system of both, which is presented to us in the first chapter of Genesis; or, is it possible that we could adopt any conjecture more absurd, and this, too, in utter destitution of all proof that the Egyptians possessed any knowledge of geology in the sense in which we use the term?

"The result of our inquiry is, that the geology of Moses has come down to us out of a period of remote antiquity, before the light of human science arose; for, to suppose that it was borrowed from, or possessed by any other people than the remarkable race to which Moses himself belonged, involves us, on all hands, in the most inextricable difficulties and palpable absurdities. Of that race, it has been long since justly remarked, that while in religion they were men, in human learning and science they were children; and if we find in their records any perfect system of an extensive and difficult science, we know they have not obtained it by the regular processes of observation and induction, which in the hands of European philosophers, have led to a high degree of perfection in many sciences."

Professor Jameson proceeds to remark:—

"The term, the meaning of which we shall first investigate, is '*day*' (in the Hebrew, yom.) The interpretation of this, in the sense '*epoch*' or '*period*,' has been a subject of animadversion, of unnecessary severity in some cases. A careful examination of the first chapter of Genesis itself, leads unavoidably to the con-

clusion, that our natural day of one revolution of the sun cannot be meant by it, for we find that no fewer than three of the six days had passed before the measure of our present day was established. It was only on the fourth day, or epoch of the creation, that "God made two great lights to divide the day from the night, and to be for signs, and for seasons, and for days, and for years.' The very first time that the term occurs in the Hebrew text, after the history of the six days' work, and of the rest of the seventh, as if to furnish us with definite information regarding its true import, we find it employed in a similar manner to that in which we must understand it here; for, in Gen. ii, 4, we have, 'These are the generations of the heavens and the earth, *in the day* (beyom) that the Lord God made the earth and heavens.' The use of the term in this indefinite sense is so common in the Hebrew writings, that it would be a great labor to quote all the passages in which it is found; and we shall satisfy ourselves by at present referring to Job xviii, 20, where it is put for the whole period of a man's life, 'They that come after him shall be astonished at *his day*,' (yomu,) speaking of the life of the wicked; and Isaiah xxx, 8, where it is put for all future time, 'Now go note it in a book, that it may be for the latter *day* (leyom) for ever and ever.'"

We will here cite the following passages to the same intent.

Luke xvii, 24.—So also shall the son of man be in his *day*.

John viii, 56.—Your father, Abraham, rejoiced to see my day; and he saw it and was glad.

2 Peter iii, 8.—One day is with the Lord as a thousand years, and a thousand years as one day.

Job xiv, 6.—Turn from him, that he may rest till he shall accomplish as an hireling his day.

Ezekiel xxi, 25.—And thou profane wicked prince of Israel, whose day is come, when iniquity shall have an end.

Proverbs vi, 34.—For jealousy is the rage of a man; therefore he will not spare in the day of vengeance.

"It is quite obvious, from these examples, that the Hebrews used the term (yom) to express long periods of time. The very conditions of the history in this chapter, prove that it must be here so understood."

"They who object to this interpretation of the term here, immediately quote against it the reason added to the fourth commandment, 'For in six days the Lord made heaven and earth, the sea, and all that in them is, and rested the seventh day, wherefore the Lord blessed the Sabbath-day and sanctified it.' This is, however, no more than a brief reference, and the terms of it must therefore be strictly interpreted in accordance with those of the detail to which the reference is made."*

"It has been said that such an interpretation goes to nullify the reasons assigned for the sanctification of every seventh revolution of the sun; but this does not follow. In point of fact, the rest from the work of creation (we use this form of speech from the example before us) did not endure for only one revolution of the sun, but has continued since the creation of man; and we have no grounds on which to establish even a conjecture of the time of its coming to a close; so that if we were urged to adopt a period of twenty four hours as the meaning of yom, that the six days of creation might literally correspond with our six working days, we should then find the apparent disagreement, which, by this process, we would endeavor to avoid, transferred to our weekly period of rest, and the rest from the work of creation."

"It will surely be readily allowed, that the sanctification of the Sabbath has respect to man and his duties; and since his Creator has been made known to him, and the order of the six successive epochs in which the earth was rendered fit for his habitation; if we are to allow, what surely no reflecting mind will ever deny, that it is his duty to reflect with gratitude on the blessing he has received, and to maintain in his heart a sense of his dependence upon, and responsibility to him, who made the heavens and the earth, and all that they contain, no method could have been devised better calculated for preserving these feelings in constant activity, than appointing some definite portion of time, returning at short intervals, to be devoted to the contemplations that awaken them, nor any interval more appropriate than that which so directly recalls the order of the events of the creation."

---

* In accordance also with the popular acceptation of the length of the days of the creation, to which the allusions in the Scriptures are, every where, necessarily accommodated.

"Since we have introduced the subject of the measure of our present day, we would offer an observation regarding the work of the fourth day, which includes the sun, moon and stars. Respecting the period of their creation, geology, from its nature, gives us no precisely definite indications. The history regarding them is from the 14th to the 18th verses, and we would observe of it, that the terms employed are such as do not absolutely imply that these bodies were at this epoch first created, but admit of the interpretation that their motions were then first made the measures of our present days and seasons. We had found it already stated in the first verse, that the heavens and the earth were created *in the beginning*, antecedently to the work of six days, by which they were reduced to their present order, and the earth was peopled with organized beings. It would seem an unwarrantable interpretation to exclude the sun, moon and stars from among the objects expressed by the general terms, the heavens and the earth. It is the most obvious interpretation, that they were then created, and were lighted up on the first day, but that it was only during the fourth epoch they were made, the greater light to rule over the present day, and the lesser light to rule over the present night, and to be for signs, and for seasons, and for days and years, according to the measures of time, which we now find established by them. This part of the history, then, when interpreted in consistency with the first verse, and without any violence to the terms, implies, (in the common language of men, which, in all nations, refers the diurnal and annual revolutions of the heavenly bodies to the motions of these bodies themselves,) that the earth was, during this epoch, finally brought into its present orbit."

"The work of the third epoch was the appearance of the dry land, and the creation of the vegetable kingdom."

In following Professor Jameson, we shall here omit his critical remarks on the meaning of the Hebrew words in the original history, of the correctness of which Hebrew scholars will judge, and proceed at once to his conclusion, which is that it is very probable the cryptogamous vegetation was the first created; and this corresponds sufficiently well with the prevailing character of the earliest plants. This is a remarkable epoch, when the waters

were gathered together into one place, and the dry land began to appear; or, in geological language, the first mountain top raised its crest above the waters of that shoreless ocean. Before this period, there could have been no terrestrial plants, for there was neither soil nor fixture. Internal fire, doubtless, lifted the emerging islands and continents, while the desolation of the universal waters began to be cheered by the verdure of plants, the beauty of flowers, and the fragrance of fruits. Not far from this period also, as we learn from their fossilized remains, were created those early animals, which being entirely immersed in the ocean, and destined never to raise themselves above its surface, made no figure in the drama of creation, and are therefore passed over in silence in the brief roll-call of beings that were first called into life. In proceeding to those animals which are next announced, our author arrives at some important conclusions that appear worthy of great confidence. Omitting his criticisms, as before, we give the results.

The creations of the fifth epoch are evidently not great whales, as usually understood, but great reptiles; and the entire work of the fifth day appears to have included things that rapidly multiplied in the waters, great reptiles, birds, and winged insects. This corresponds wonderfully with the contents of the rocks* belonging to this period, the animals being altogether oviparous, and none of them viviparous.

Lastly, in the sixth period, the terrestrial animals, mammalia and man, are called into being, and we know how well this agrees with the contents of the upper strata, where alone (with a solitary exception) viviparous animals are found, and man no where except at the surface. The following table of geological coincidences, drawn up by Professor Jameson, may need a few additions and alterations to accommodate it to more recent observations, but is still mainly correct.

---

* In our remarks upon the successive rock formations, we have purposely omitted any allusion to the metamorphic theory espoused by the Huttonian school, ably illustrated by Mr. Lyell, and carried to an incredible extreme by Prof. Keilhau in his account of the rocks around Christiana, Norway, where, according to him, granite passes, by insensible gradations, into slates replete with organic remains. His observations are very curious, and many of them original, but they will demand a very strict revision.—*See Jameson's Edinb. Jour. Vol.* 25, *pp.* 80—203.

Table of Coincidences between the Order of Events as described in Genesis, and that unfolded by Geological Investigation.

In Genesis.	*No.*	*Discovered by Geology.*
Gen. I. 1, 2. In the beginning God created the heavens and the earth. And the earth was without form and void; and darkness was upon the face of the deep; and the Spirit of God moved upon the face of the waters.	1	It is impossible to deny, that the waters of the sea have formerly, and for a long time, covered those masses of matter which now constitute our highest mountains;
3, 4, 5. *Creation of light.* 6, 7, 8. *Creation of the expansion or atmosphere.* 9, 10. Appearance of the dry land.	2	and, further, that these waters, during a long time, did not support any living bodies.—*Cuvier's Theory of the Earth, sect.* 7.
11, 12, 13. Creation of shooting plants, and of seed-bearing herbs and trees.	3	1. Cryptogamous plants in the coal strata.*—*Many observers.* 2. Species of the most perfect developed class, the Dicotyledonous, already appear in the period of the secondary formations, and the first traces of them can be shown in the oldest strata of the secondary formation; while they uninterruptedly increase in the successive formations.—*Prof. Jameson's remarks on the Ancient Flora of the Earth.*
14 to 19. *Sun, moon and stars made to be for signs, and for seasons, and for days, and for years.*		
20. Creation of the inhabitants of the waters.	4	Shells† in Alpine and Jura limestone.—*Humboldt's tables.* Fish in Jura limestone.—*Do.* Teeth and scales of fish in Tilgate sandstone.—*Dr. Mantell.*
Creation of flying things.	5	Bones of birds in Tilgate sandstone.—*Dr. Mantell, Geological Transactions,* 1826. Elytra (sheaths) of winged insects in calcareous slate at Stonesfield.—*Dr. Mantell.*
21. The creation of great reptiles.	6	It will be impossible not to acknowledge as a certain truth, the number, the largeness, and the variety of the reptiles, which inhabited the seas or the land at the epoch in which the strata of Jura were deposited.—*Cuvier's Ossem. Foss.* There was a period when the earth was peopled by oviparous quadrupeds of the most appalling magnitude. Reptiles were the lords of creation.—*Dr. Mantell.*

* It would appear that the earliest animals not named by Moses were cotemporary with, perhaps subsequent to, the first plants.—Ed.

† Shells are found also in the earliest periods in the transition; the Jura limestone is coeval with the chalk formation. Fish are found below the coal, and in the transition rocks. Tracks of birds and reptiles in new red sandstone, in Connecticut and Germany.—Ed.

In Genesis.	No.	Discovered by Geology.
24, 25. Creation of the mammalia.	7	Bones of mammiferous land quadrupeds,* found only when we come up to the formations above the coarse limestone, which is above the chalk.†—*Cuvier's Theory, sect.* 20.
26, 27. Creation of man.	8	No human remains among extraneous fossils.—*Cuvier's Theory, sect.* 32. But found covered with mud in caves‡ of Bize.—*Journal.*
Genesis, VII. The flood of Noah, 4200 years ago.	9	The crust of the globe has been subjected to a great and sudden revolution, which cannot be dated much farther back than five or six thousand years ago.—*Cuvier's Theory,* 32, 33, 34, 35, *and Buckland's Reliq. Diluv.*

The following remarks in illustration of this table as a summary of the subject, are too interesting to be omitted.

"In the above table we have not taken advantage of the distinction, which we conceive we have gone far to prove is expressed in the Hebrew text, between the cryptogamous and the other classes of plants, but have set downt he whole vegetable kingdom as forming only one element in the table. We shall also allow that the 4th, 5th, and 6th numbers may be liable to be interchanged among themselves in respect of place, and shall hinge no argument upon them farther than what arises from the circumstance that they are all placed in one group. Yet, after these abatements from the number of particulars, the coincidences here shown between the order of the epochs of creation assigned in Genesis, and that discovered by geology, are calculated to excite the deepest attention. Human science, in the probability of

* It has been objected to the geological account of the death of animals found in the rocks, that as death came into the world by sin, there could have been no death until after the fall of Adam. Most evidently the death referred to is the spiritual death of the human race; we do not object to its being explained so as to include also their physical death, but plainly it has no reference whatever to the death of animals. The carnivorous regimen established among particular genera of all the classes of animals, sufficiently proves that the death of some was indispensable to the continuance of others in life; and Dr. Buckland has shown that it is on the whole a dispensation of mercy, as the amount of animal enjoyment is thereby much increased as well as by their natural death; otherwise the world would be overrun with aged and infirm races and individuals.—Ed.

† One solitary exception is since discovered in the calcareous slate of Stonesfield, in the bones of a didelphis, an opossum, belonging to a tribe of animals whose position may be held to be intermediate between the oviparous and mammiferous races.

‡ And in Guadaloupe and Brazil, in a recent concretionary limestone.—Ed.

chances, as illustrated by La Place, has put us in possession of an instrument for estimating their value; and we feel amply entitled to take advantage of it for that purpose, for no case could well be pointed out where it would be more correctly applicable than in this, where the coincidences assume a definitely successive numerical form. We are entitled to adopt even the very language of La Place, and to say, 'By subjecting the probability of these coincidences to computation, it is found that there is more than sixty thousand to one against the hypothesis that they are the effect of chance.'*

"It is thus then that the discoveries of geology, when more matured, instead of throwing suspicion on the truths of revelation, as the first steps in them led some persons to maintain, have furnished the most overpowering evidence in behalf of one branch of these truths. The result of these discoveries has been in this respect similar to those of the Chinese and Egyptian histories and the Indian astronomy, but much more striking. Eminent men had pledged their fame in setting up these histories, and that astronomy, in opposition to the chronology of Genesis; but farther and more careful inquiry into their true characters, discovered, that when rightly understood, they only tended to confirm it."

"We are not afraid that we shall have here quoted against us the words of Bacon, 'Tanto magis hæc vanitas inhibenda venit, et coercenda, quia ex divinorum et humanorum, male sana admixtione, non solum educitur, philosophia phantastica, sed etiam religio hæretica.' We have only endeavored to illustrate and point out the consequences of the statement of Baron Cuvier, 'that the order which the cosmogony of Moses assigns to the different epochs of creation, is precisely the same as that which has been deduced from geological considerations.' We have been guilty of no improper mixing up of divine and human things. We have examined the meaning of the terms in the first chapter of Genesis, in consistency with the acknowledged rules of criticism, and only by the light contained within itself, or that thrown upon it by the other books in the same language with which it is associated. The human science we have not extracted from any part of the Holy Scriptures; we

* Syst. du Monde, book v, chap. 5.

have taken it simply as we find it in the works of eminent geologists. As the latter is not a philosophia phantastica, but a deeply interesting science, constructed by that method of careful observation and cautious induction, which Bacon was himself the first to recommend; so neither can the sense of the Scriptures present to us a religio hæretica. If our science, thus constructed, and our religion speak so obviously the same language, as we see they do on one important point, what else in the strictest application of Bacon's philosophy, can we deduce from the circumstance, but that both are certainly true?"

"It does not come under our present subject to discuss the historical and moral evidences of the divine revelation of the Scriptures; but both are so full, even to overflowing, and impose upon us so many insuperable difficulties in the way of our being able to account for the quality and consistency of these remarkable books, excepting on the ground which has been all along assumed by themselves, that they are of more than human origin, that in estimating the accuracy of any part of the matters contained in them, the fastidiousness of human science appears to be carried to an unreasonable extent, not to take these evidences into calculation. In this country,* where for a long period we have had the Scriptures in our hands as a popular book, they among us who have been the most eminent for human learning and science, and whose fame has been in every view the most unsullied, have been so convinced by the force of these evidences, that they have in general been the most strenuous defenders of revelation."

"Will not human science, then, condescend to borrow some light to direct the steps of its own inquiries, from a record the accuracy of which it has itself proved, and which is supported by other proofs of the highest order? Or,† what should we say to the illustrator of the relics of Pompeii and Herculaneum, who should reject the light thrown on them by the letters of Pliny, authenticated as these are by the existing remains of the buried cities, as well as the historical evidence which is proper to themselves."

---

* Scotland, but the author's remark applies with equal force in this country.—Ed.

† This argument we attempted to illustrate in the early part of the present discussion.—Ed.

RECAPITULATION.

The opinions of Professor Jameson illustrating the views of the lamented Cuvier, being those that are satisfactory to ourselves, we have quoted them with few omissions.

We now proceed to remark, that we are aware, from much communication on this subject with eminent biblical critics and divines, how tenacious they are, in common with the less enlightened Christian world, of the common acceptation of the word day. On points of verbal criticism we will not presume to speak with great confidence, but from much consideration, aided by the light both of criticism and geology, it does not appear to us necessary to limit the word day, in this account, to the period of twenty four hours.

1. This word could have no definite application before the present measure of a day and night was established by the instituted revolution of the earth on its axis, *before an illuminated sun*, and this did not happen until the fourth period.

2. The word day, in accordance with the practice of all languages, is used even in this short history, in three senses: for light as distinct from darkness, for the light and darkness of a single terrestrial revolution, or a natural day; and, finally, for time at large.

3. In the latter case then the account itself uses the word day in the sense in which geology would choose to adopt it, that is, for time or a period of time.

This latter fact appears to be overlooked or neglected by most of those who have criticised the views of geologists, as Professor Jameson justly remarks, "with an unnecessary severity;" but we have a right to hold them to this case, which is exactly in point, being presented precisely where we should wish to find it, and we shall therefore regard it as proving our point; for in the recapitulatory view of the creation in the beginning of the second chapter of Genesis, allusion is made to the whole work, in the expression "*in the day* that the Lord God made the heavens and the earth."

4. If the canons of criticism require that one sense of the word day should be adopted and preserved throughout the whole account, how are we to understand this verse? "These are the gen-

erations of the heavens and the earth when they were created, *in the day* that the Lord God made the heavens and the earth." Which of the three senses shall we adopt? If the most common, then the whole work was performed not in six days, but in one day—of twenty four hours in the popular sense; but according to the geological views the work was done in a sufficient time, be it more or less. The canons of criticism were made by man, and may therefore be erroneous, or at least they may be erroneously applied; the world was made by God, and if the history in question were dictated by him, it cannot be inconsistent with the facts. Why then should we not prefer that sense of the word used in the history itself, which is in harmony with the structure of the globe! It is said indeed by some critics, that the account in the second chapter of Genesis is a different one from that in the first; but with this opinion the geologist, as such, can have no concern; and since he finds both accounts in a connected history, he receives them as one.

It is agreed on all hands, that the Hebrew word here used for day, although frequently used for time, usually signified a period of twenty four hours; and the addition of morning and evening is supposed to render it certain that, in the present case, this is the real sense and the only one that is admissible, especially as this view is said to be supported by the peculiar genius of the Hebrew language.

But, in all languages, whenever the subject requires, it is usual to preserve this allusion to morning and evening, even when the word day is used for time; thus, when for instance we speak of the life of a man *as his day*, in harmony with the rhetorical figure we speak also of the morning and the evening of life.

In all ages, countries, and languages, as already remarked, this sense of the word day is fully sanctioned, and it is frequently so used in the Scriptures.* Indeed, it might not be too much to suppose that the arrangement by which the sun was to measure time was not completed until the evening of the 4th day, and then our difficulties will be confined to one day, namely, the 5th. The first three days, obviously, could not have had the present measure of time applied to them, and their morning and evening must there-

* See the instances already cited on page 558.

fore have been figurative; an arbitrary division of time, accommodated to the advancing creation, and the work of arranging the crust of the planet was so far finished by the evening of the 5th day, as to fit it for the reception of terrestrial quadrupeds, which first appeared on the 6th day, and finally, man was created, as would appear, at the conclusion of the same day; of course, the great geological revolutions, *beneath the bed of the ancient ocean*, must have been so far finished on the 3d day that the continents began to emerge, and thus dry land began to be provided not only for vegetables, but for terrestrial quadrupeds and for man, neither of which could, before this period, have existed on the earth. All this was done before the present measure of time was applied; we do not say before there was light, for elementary light was "the first born of the creation," nor even before the sun shone, but before he was set "to rule over the day and over the night."

In the usual mode of understanding the account, all the immense deposits of coal, and of early vegetable remains and marine animals, with their vast strata and mountains, the grand mausoleums in which they lie entombed, must have been made within seventy two hours, for there was no dry land until the 3d day, and consequently no terrestrial vegetables; they appeared on that day, aquatic animals on the 5th, and land animals, with man, on the 6th; but the latter could not, as observed above, have appeared until the continents had emerged.

According to the popular understanding, the transition and secondary mountains with their coal beds, plants, and animals were therefore formed, by physical laws, in two or three natural days, which is incredible, because it is impossible.

We cannot conceive, therefore, that even the limitation of morning and evening is decisive against the extension which we would claim, and we are left at liberty to interpret the word day in harmony with the facts of geology.

It is granted that Moses himself probably understood the word day according to the popular signification, and as regards the history in question, this sense is certainly the most obvious one to every mind not informed as to the structure of the globe; even those who are learned on other subjects, but ignorant of geology, always adopt, in this case, the literal and obvious meaning. This however proves nothing; for the truths of astronomy are in ex-

actly the same situation. Until the modern astronomy arose, no one, whether learned or unlearned, entertained a doubt that the earth is an extended plain; that it stands on a firm foundation, even on pillars, and that around it as a center, the sun and starry heavens and the azure canopy, as a solid palpable firmament, revolve, while the waters of the heavens descend through its windows.*

Such is still the impression of barbarous nations, while few even of the common people of enlightened countries would now fall into so gross an error; and no one in this age fears that he shall, like Galileo, be thrown into prison for declining (on this subject) to understand the Scriptures in their literal sense.†

It is objected as already stated, that as the sabbath is a common day, and that as it is mentioned in the fourth commandment, and in other parts of the Scriptures, in connection with the other six days, they ought to be limited to the same *time.*

We cannot see that this consequence follows. The sabbath is a moral enactment; all that precedes was physical, relating merely to the creation and arrangement of matter, and to irrational organized beings; the sabbath could have no relation to rocks and waters, vegetables and animals: it was ordained for man, as a rational being, to bring back his thoughts to his Creator by a day which naturally recalls the great act of creation; and in mercy as a day of rest from labor both for him and for the animal races that

---

* For an admirable view of the inconsistencies of those who would adopt the light of science as regards the firmament, the rains, and the starry host, and celestial space, and deny the same liberty to geology as regards extension of time, see Am. Journ. of Science and Arts, Vol. xxx, p. 114, Sig. K.

† When the present system of astronomy was introduced, it met with the most violent opposition, and the following is the "Judgment pronounced at Rome, in 1622, only two hundred and seventeen years ago, on the Philosophy of Galileo, and on the Philosopher himself, by the seven Cardinal Inquisitors." "To affirm that the sun is in the center, absolutely immoveable, and without locomotion, is an *absurd* proposition, *false* in sound philosophy, and moreover *heretical*, because it is expressly contrary to *Holy Scripture.* To say that the earth is not placed in the middle of the world, nor immoveable, is also a proposition *absurd and false* in sound philosophy; and considered theologically, is at least erroneous with respect to faith." "Whereupon Galileo so refuted, was compelled on his knees to abjure, curse, and detest the *absurdities, errors and heresies*, which the sagacity of the Cardinal Reviewers and Inquisitors had discovered in his writings."—*Penn's Compar. Estimate, &c., 2d Ed. Vol. I, p. 37.*

were to labor for him: it was a new dispensation, and although the same word is applied both to this period and to those that preceded, it does not appear to follow that the original periods were then, as they are now, of the same length. As the first three days that preceded the establishment of the relation between the sun and the earth could have no measure of time in common with our present experience, it appears to be no unwarrantable liberty to suppose that they may have been of any length which the subject matter may require, although those three days were also verbally limited by morning and evening, and that at a period of the creation when there could have been no morning and evening, in the sense in which those words are now used. It is very remarkable that the seventh day is not limited at all, either by morning or evening, like the other days, and although it must have been actually limited as to its beginning, it does not appear that as a day of rest and cessation from the work of creation it is even yet ended, after nearly 6000 years; therefore as regards the Supreme Being it has been already of that length, and we know not when it will end.

The revolution of the earth on its axis in the presence of an illuminated sun being necessary to constitute morning and evening, it must also revolve with the same degree of rapidity as now, in order to constitute such a natural day, with its morning and evening, as we at present enjoy. But as already suggested, the sun not being ordained to rule the day until the fourth of those periods, it is not certain that even after this epoch, those early revolutions of the earth on its axis were as rapid as now; for these might cease altogether, or be greatly increased in rapidity, without affecting the planetary relations of the earth with the sun and with the other members of the system. The historian, as he must employ some term for his divisions of time, naturally adopted one that he found in familiar use, but it appears, both from the subject matter to which it is applied, and from the use made of it in this very history, that the word day is not in the present case necessarily restricted to its most common acceptation.

Is it asked whether Moses had any mental reservation, a double sense for the word day—one for the common people and one for men of science; we answer that as it appears from his brief, sim-

ple and merely optical statement, that he had no astronomical knowledge beyond what was current among the Egyptians of that day, so it is almost certain that he had no geological knowledge beyond the order of time and events in the creation which his history exhibits. It is very probable that fossil and entombed organized remains and fragmentary rocks, and indeed most of the facts which geology has developed, were unknown to him, that he had observed little on this subject beyond the annual sedimentary deposits of the Nile, and that, as he told a story for mankind at large, he told it in the same spirit and with the same understanding with which it is commonly received. This however decides nothing more than in the case of all the sacred writers who relate astronomical events, or who allude to astronomical appearances in the vulgar sense, which is in direct contradiction to the actual state of facts in astronomy; whereas geology contradicts nothing contained in the Scripture account of the creation; on the contrary, it confirms the order of time and events, and requires only that the time should be sufficiently extended to render it physically possible that the events should happen, without calling in the aid of miracles in a case where natural successions are sufficient to account for all the facts.

It may be worthy of remark, that supposing that there are inhabitants at the poles of the earth, to them a day of light is six months long, and a night of darkness is six months long, and the day, made up of night and day, covers a year, and it is a day too, *limited by morning and evening.*

So *at* the polar circles there is once in every year a continued vision of the sun for 24 hours, and once in the year a continued night of 24 hours; while every where within the polar circles, the days and the nights respectively are for six months, more than 24 hours long, extending even, as we advance towards the poles, through the time of many of our days and nights. How are these people to understand the week of the creation, if limited to the popular view entertained in countries between the polar circles?

In Mercury the day is		24½	hours long.
In Venus	"	over 23	" "
In Mars	"	24h. 40m.	"
In Jupiter	"	nearly 6 hours	"

In Saturn the day is over 10 hours long.
In our Moon " a lunar month.

Thus it appears that the actual days of the planets differ considerably, and that of the earth* differs remarkably at and within the polar circles, as those in lower latitudes differ very much from each other.

The result of all our inquiries, then, is this.

We find that the geological formations are in accordance with the Mosaic account of the creation; but more time is required for the necessary events of the creation than is consistent with the common understanding of the days. The history therefore is true, but it must be understood so as to be consistent with itself and with the facts.

It is agreed on all hands, that there may be time enough for the central rocks before the first day; we have already given our reason why we cannot throw back the creation of organized beings into the indefinite period that precedes the first day; vegetables and animals are introduced in connection with the days and not before, and there is no reason to suppose that there has been a double creation or merely a new arrangement of fragments and ruins; therefore if the days be regarded as periods of time, so as to allow room for the events assigned to them, relating to organic beings, and to the masses in which they are entombed, all difficulty is removed.

On the contrary, if they are restricted to the usual popular sense, it is not physically possible that the events should have happened within the time assigned; but they did happen, and as there was no call for miracles in cases where natural operations alone were sufficient, there can be no doubt that sufficient time was allowed.

It is scarcely necessary to remark, that when the order and arrangement of creation was fully finished, and man appeared on the earth, the measures of time were, without doubt, finally established the same as now, and therefore we are not at liberty, as

* An eminent biblical critic and Hebraist, now in Europe, once remarked to me, when speaking of the word day as used in the first chapter of Genesis, that the use of the word in the three first days was *mere costume*, (manner,) and if so in those cases, why, added he, may they not be so considered in all?

there is clearly no occasion, to regard them in any other than the usually accepted sense.

It is no valid objection to the supposition of more time than is commonly allotted to the week of the creation, that there were no human beings to be spectators of the work. Even upon the popular view they were excluded, because the human race did not appear until the very last act of the creation. Had they, however, been co-existent, they would scarcely have understood what was passing, as most of the geological facts were veiled by the ocean. But there were not wanting spectators; God, and angelic beings, far superior in intelligence and dignity to man, looked on, while in the beautiful and highly figurative language of the Scriptures—" the morning stars sang together, and all the sons of God shouted for joy."*

Before closing these remarks, we will respectfully submit a few suggestions for the consideration of two very different descriptions of persons, namely, *those who deny, and those who defend, the truth of the Mosaic history.*

To the former class, so far as they are geologists, we will say, that, in relation to geology, any attempt to disprove the truth or genuineness of the Pentateuch, and of Genesis in particular, is wholly superfluous, and quite aside from any question that can, in this age, be at issue between geologists. No geologist, at the present day, erects any system upon the basis of Scripture history, or any other history. Still, historical coincidences with natural phenomena have always been regarded as interesting, because they are mutually adjuvant and confirmatory. The letter of Pliny, describing the death of his uncle, would have been true, although Herculaneum and Pompeii had never been discovered; and it would have been true that those towns were overwhelmed by a volcanic eruption, although the letter of Pliny had never been written; or being written, if it had been false as to the main fact of the death of the elder Pliny, or of their having been an eruption at the time assigned in that writing. But an authentic letter exists describing the event, and as it coincides with the facts revealed by the discovery of the buried cities, conviction

* In this summary we have found it necessary to repeat some remarks in a new connexion.

flashes upon every mind, and the unexpected and beautiful coincidence, like many of those that add strength to the evidence in support of the sacred volume, affords one of those firm points of reliance upon which our confidence reposes with delight. Now if there is not sufficient proof in the appearance of the earth, that it was for a long time covered by water, and that the waters deposited, in the then forming strata and mountains, those organic bodies, of aquatic origin, which we find entombed in them, then no geologist of the present day would, in that character, on the authority of the first chapter of Genesis alone, assume the fact of terrene submersion, as the basis of his reasoning and as the foundation of a geological system.

In the same manner, if he find on the face of the earth no proofs of diluvial devastation; if there be nothing to evince, that mighty rushing waters have torn up and transported to a distance the movable materials of the surface; then, as a geologist, he will never assume the Mosaic account of the deluge as the basis of a system of diluvial agency, any more than he will build similar conclusions upon the poetry, fables, and mythology, or even upon the history, of the ancients. But if he discover proofs, and those too, generally admitted by well instructed geologists, of both the stupendous events named above, or of a succession and diversity of such events, sufficient, on the whole, to mark the entire earth by the effects appropriate to each; if then he finds a history of high antiquity, and generally revered wherever known, describing such a state of things as the condition of the planet reveals, what rule of science or of philosophy can debar him from bringing the two into comparison, for mutual illustration, as is always done in the case of other antiquities. Why should any one object to his applying the terms of the history, as he understands them, and then measuring the phenomena by them, and them by the phenomena? If they agree, surely, it is reasonable that conviction should receive augmented strength in his mind. Should they, however, disagree, the phenomena, if correctly observed and correctly reported, will still be true, and the credit of the history will, of course, be impaired. Should, moreover, the genuineness or authenticity of the history be disproved, from other sources than the phenomena, the latter will still remain in all the obstinacy of

immutable fact, which history may indeed illustrate, but cannot, on the contrary, disprove. If the history, on the other hand, be confirmed by the natural phenomena, it has then received the greatest confirmation possible, and may well exult in so powerful an ally.

Should it, in the case of the Pentateuch, be proved even, that there was never any such person as Moses, or that the books that pass under his name were written by others, or that they are compilations of ancient and vague traditions, or even of reputed or real fables, this would not, in the least, affect the system of geological truth that has been erected by an ample course of investigation and induction. But, as long as the Mosaic history is admitted to be both *genuine* and *true*, any geologist who receives the history in that character, may, with strict historical and philosophical propriety, illustrate the history by geology, and compare geology with the history.

This he will do merely on the ground of historical and geological coincidence, and without drawing for the support of his scientific views upon any portion of his moral feeling, towards a work which, as an individual, he may revere as a communication from his Maker, for purposes far more important than the establishment of physical truth.

To personal imputations on his motives, his science or his skill, or on those of eminent philosophers with whom he has the honor to think and to act, while he leaves the case, with the grand inquest of the learned, the candid and the wise, he will reply in no other manner than by expressing the hope that powerful and cultivated, but *unbelieving* minds, minds confiding implicitly in physical, but *sceptical* with respect to moral truth, may be influenced to see the harmony *of all truth*, whether historical, moral or physical, and to remember that man is, after all his acquirements in knowledge, a being, so darkly wise, although rudely great, that he is constantly in danger of error, error against which he should the more studiously guard when the physical subjects which may be the objects of his study have also a high moral relation. While, therefore, in geology, as well as in other sciences, we fully approve, and follow the course of rigid induction—(the only safe and truly philosophical process of investigation, and

solid basis of physical truth,) we hold it to be entirely proper in a scientific view, to avail ourselves of every apposite historical fact, from whatever credible source it may be derived. Indeed, no geologist hesitates to cite history, travels, personal narrative, and even poetry and tradition, in confirmation or illustration of earthquakes, floods, or volcanic eruptions; of the rising or sinking of islands; of alluvial increase or destruction; of ruptures of the barriers of lakes; of irruptions of the sea—or whatever other fact may be the subject of his investigation. Why then should the Scripture history form the only exception among historical authorities?

Having made these suggestions to those geologists who are not believers in divine revelation, we will now address a few remarks to believers who are not geologists.

The subject before us is not one which can be advantageously discussed with the people at large. A wide range of facts, a familiarity with physical science, and an extensive course of induction, are necessary to the satisfactory exhibition of geological truths, and especially to establish their connexion and harmony with the Mosaic history. It is a subject exclusively for the learned, or at least for the studious and the reflecting; but as regards their own mental furniture, it can no longer be neglected with safety, by those whose province it is to illustrate and defend the sacred writings. The crude, vague, unskilful, and unlearned manner, in which it has been too often treated, when treated at all, by those who are, to a great extent, ignorant of the structure of the globe, or who have never studied it with any efficient attention, can communicate only pain to those friends of the Bible, who are perfectly satisfied, after full examination, that the relation of geology to sacred history, is now as little understood by many theologians, and biblical critics, as astronomy was in the time of Galileo.

Non tali auxilio, non defensoribus istis, tempus eget!

There is but one remedy; theologians must study geology, or if they will not, or from peculiar circumstances, cannot do it, they must be satisfied to receive its demonstrated truths from those who have learned them in the most effectual way, not only in the cabinet, but abroad on the face of nature, and in her deep recesses.

They will then be convinced that geology is not an enemy, but an ally of revealed religion; that the subject is not to be mastered by mere verbal criticism; that faithful study must be applied to facts, as well as to words, and that there is, at most, only an apparent incongruity, an incongruity which vanishes before investigation.

The mode in which the subject is now treated, or rather neglected or spurned by many theologians and critics, (not by all, for there are honorable exceptions,) is not safe, as regards its bearing on the minds of youth. If they go forth into the world in the stiffness of the letter, and without the knowledge or proper application of the facts, it is impossible that they should sustain themselves against those who, with great knowledge, and no reverence, may too powerfully assail what they cannot defend. In the pulpit, however, geology can be but very imperfectly explained, even by him who understands it; for it is impossible that he should there, intelligibly and adequately exhibit his proofs; they rest on a multitude of facts unknown to a common audience; and they are too far dependent on specimens, sections and other graphical illustrations, to be understood in such circumstances, especially by those who have enjoyed no mental preparation in kindred sciences, and in courses of inductive reasoning. Since the subject has no other connexion with our faith as Christians, than so far as it affects the credibility of the early Scripture history, it is therefore wise, as to the literal sense of the days, not to disturb the early and habitual impressions of the common people, or even of the enlightened, who are ignorant of geology. Any discussion before such audiences, and in such circumstances, will be misunderstood, or not understood at all, and will only prejudice the reputation of the speaker without benefiting the hearer.

This, however, does not excuse the theologian from being fully prepared to meet the subject in other places, and in situations where it will be forced upon his attention. *It is a part of the panoply of truth, in which he should be fully clad,* although he may rarely draw his bow, and perhaps never let fly an arrow from his appropriate watchtower.

As the case now stands, with respect to most theologians in this country, the geological arguments in support of the Mosaic

history, although powerful and convincing, are unknown and neglected, or they are denied, slighted and avoided; and of course they can be, and they actually are, by some few geologists, turned, with too much success, against the sacred records; it remains with the defenders of those records to say, whether the purloined weapons shall be returned to the armory whence they were stolen, and from which they may be again drawn forth for efficient use in support of the cause of truth.

Theologians who were trained before geology was understood, and before it was possible to acquire, in our seminaries, an adequate knowledge of its elementary truths, are not included in these remarks, and we are happy to observe the increasing attention which is paid to the subject by some students in the sacred science.

After a long course of careful study on this subject, the study of the earth in mines and mountains, as well as in books and cabinets, we feel it our duty to declare, that this noble science merits not the neglect with which it is frequently treated, nor the reproaches and hostility with which it is too often assailed. This mode of treatment will not destroy the facts, or for a moment retard the progress of truth. Were the thunders of the Vatican* now levelled at geology, as they were two centuries ago at astronomy and some of its early cultivators, it would no more avail than it then did. The march of truth is onward, and onward it will go. Denunciation, neglect or sneers, will not arrest its course, nor can ignorance or misrepresentation long hold it in dishonor. The Christian world must and will admit its established truths, and these truths teachers must learn, or their pupils will leave them in the darkness which some appear to covet.

Kind communications and instructions will remove the doubts and fears of those who are anxious lest old foundations of faith

---

* The Vatican stands acquitted on the present occasion, for it is a curious fact, both in morals and science, that the lectures of the Rev. Dr. Nicholas Wiseman, of the Catholic church, Principal of the English College, and Professor of the University of Rome, recently delivered in Rome itself, under the very eye if not the listening ear of the Pontiff, contain a view of the connexion of geology with the Scripture history, so *truly catholic*, and in the main, *so just in science*, that it may well gratify a Christian geologist, and reprove many Protestant divines.

should be disturbed, and they will perceive that the building does not totter to its fall, but that new buttresses and props have fixed it, more firmly than ever, on an immovable basis of physical as well as moral demonstration.

These suggestions have been made with the sincere and earnest hope of doing good, especially to those who greatly neglect a subject of high interest, which it much concerns them to know.* But it will be no new case, should a mediator between hostile armies fail to conciliate either party, and only provoke the artillery of both; nor would it create either surprise or displeasure, should the writer of these remarks be regarded as an intruder on consecrated ground. This ground, however, he considers as common to all the friends of truth, and among geologists there are not a few who regard the Scriptures with quite as high an interest as physical science, and who are anxious to prove, that where others discover only discord, there is a principle of harmony, which a skilful hand may draw forth, in tones delightful to all who have an ear to perceive and relish "the universal harmonies of nature."

---

* It is perhaps not improper to mention, that an eminent Hebrician and biblical scholar, who had been trained up in the common opinions, which he had cherished for many years, and had never doubted their correctness, was entirely convinced on hearing a course of geological lectures, fully illustrated by specimens and drawings. With great candor he himself came out the next season, 1835, in a public course of lectures on the subject of the creation, and in the same room, (that of the Franklin Hall at New Haven,) avowing his conviction of the truth of our geological views, fully vindicated the extension of time required by geology; even in the days themselves, as well as in the antecedent period.

See also a very able and candid discussion of this subject in the comment of Prof. Bush, late of the New York University, on the book of Genesis. We hazard nothing in predicting many conversions on this controverted subject, and ultimately perfect harmony between Christian geologists and Christian teachers.

The view taken by Prof. Bush corresponds, substantially, with that sustained by Dr. Murdock, namely, that the long periods of the creation called days, may have been made up of many shorter days, each having its morning and evening. We are in no degree anxious as to the mode in which critics may furnish an explanation consistent with the requisite extension of time, provided the time be associated with the successive creations and fossilization of the organic beings which are truly medals of the ancient world.

INDEX.

C.

D.

N.

O.

P.

Q.

R.

S.

T.

INDEX

TO PROF. SILLIMAN'S APPENDIX.

Plate 1.

Fig.1.
a
1
b
2
3
Fig.2.
B
1
2
3
4
4
3
A
2
1
C
1
2
3
Fig.3.
Fig.4.
D
C
C
Fig.5.
Fig.6.
a
b
c
d
a

Plate 2.

Fig. 2.

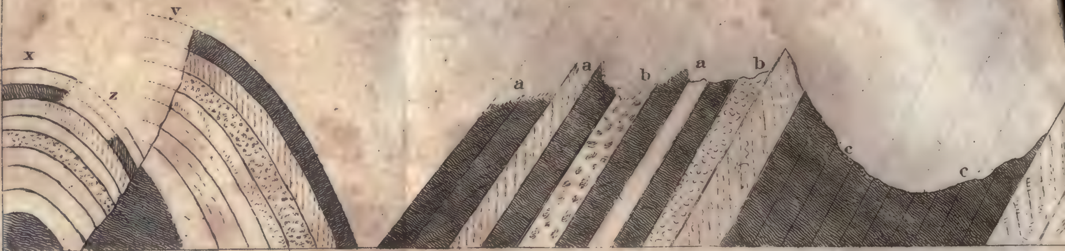


Fig. 4.

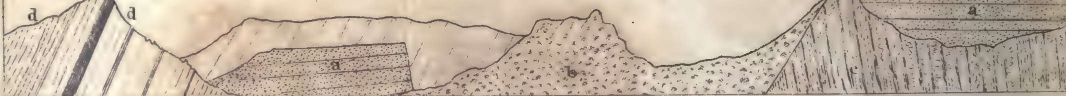
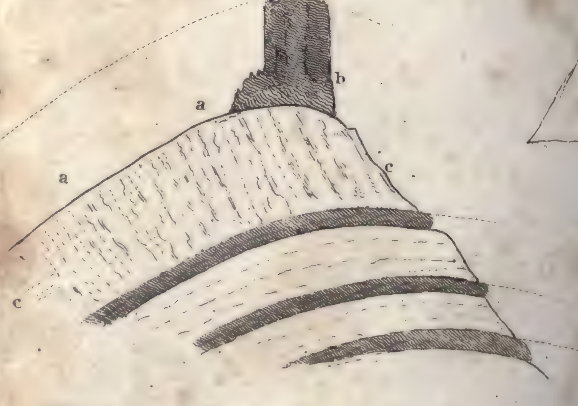
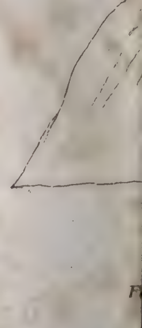
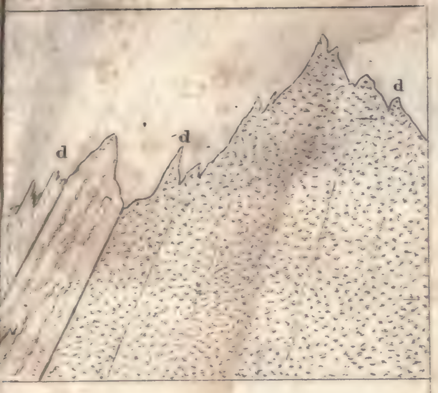


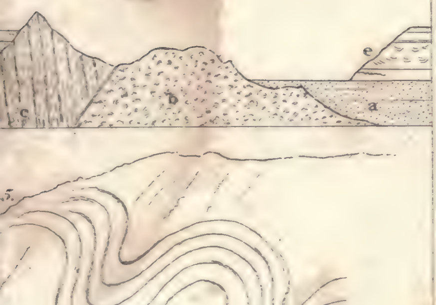
Fig. 3.

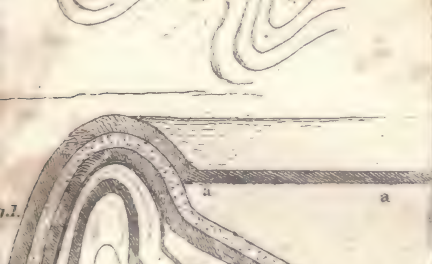
Fig. 6.

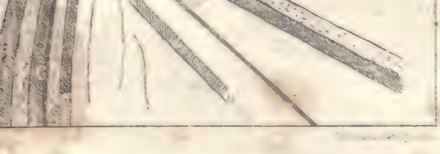





d
d
d


c
b
a
e




a
a

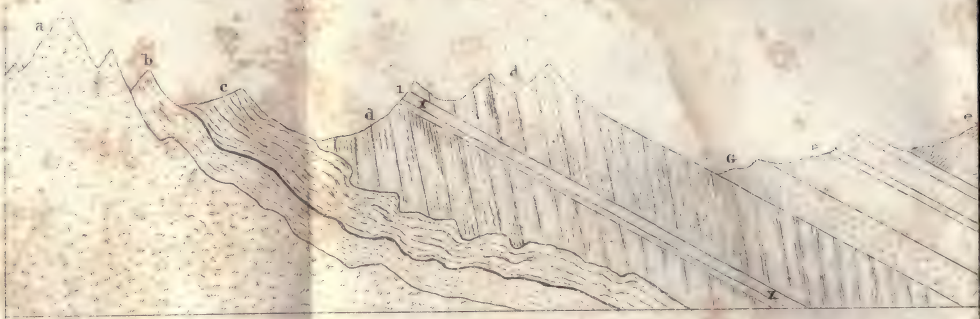


Fig. 2.

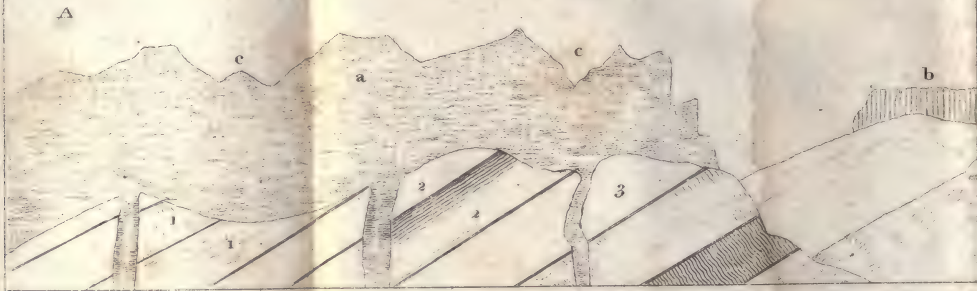
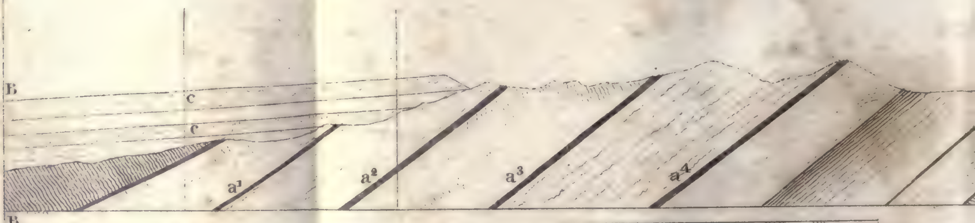


Fig. 3.



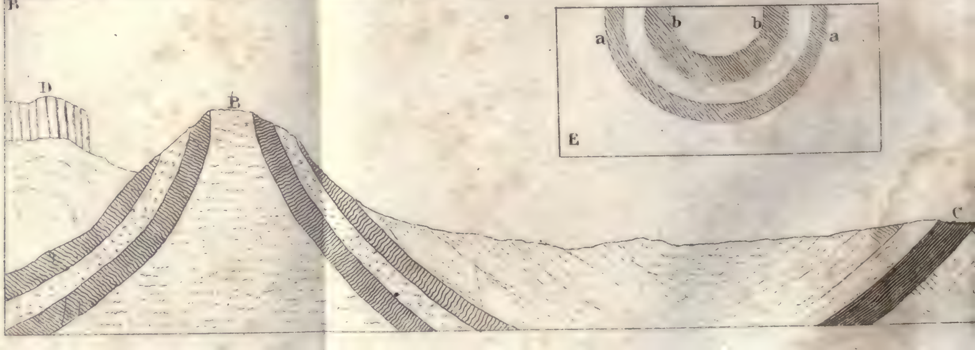
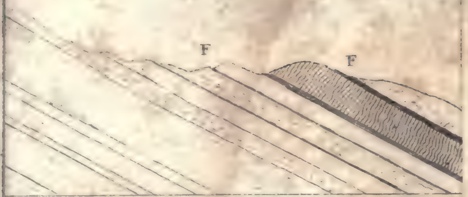


Fig. 1.



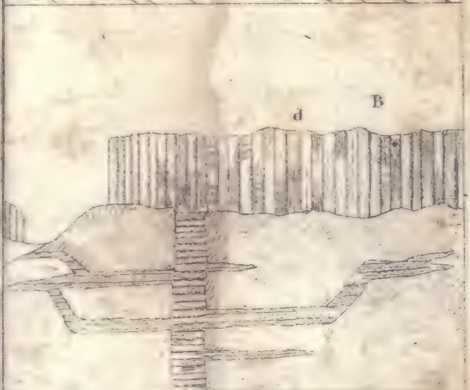


Fig. 4.

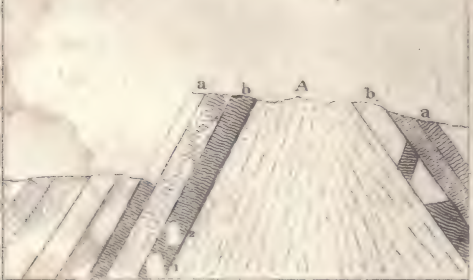


Plate 4.

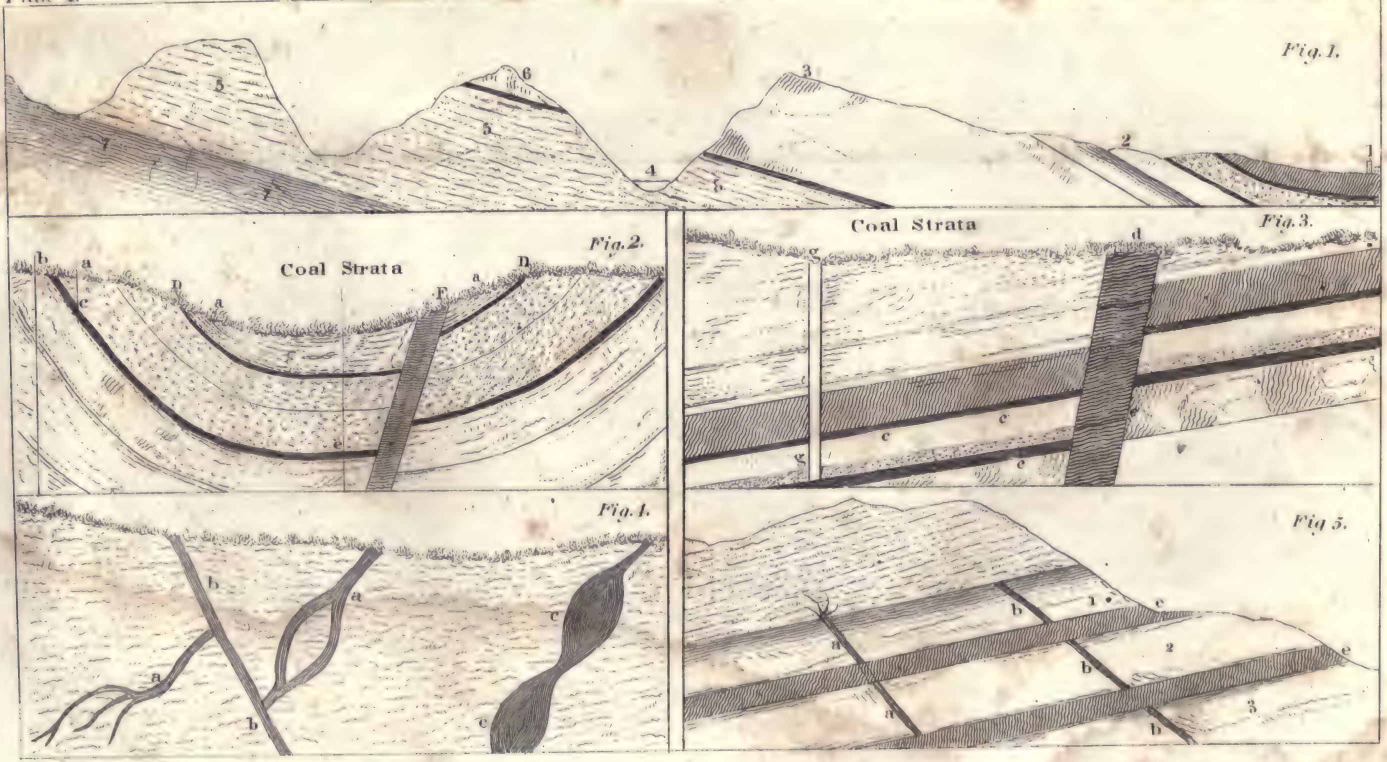


Plate 5

Fig. 1.

Fig. 2.

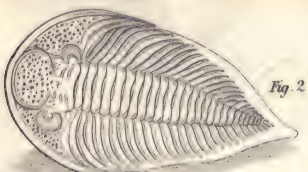
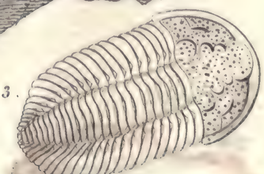


Fig. 3.



THE GIGANTIC TRILOBITE,
drawn the natural Size from a specimen in the Authors Collection.

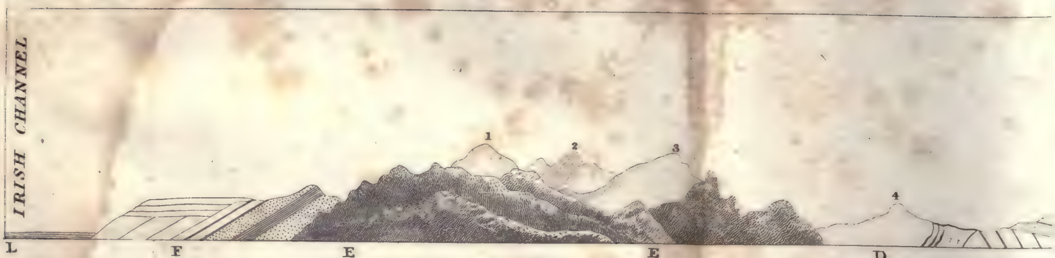
N & S. S. Jocelyn. Sc.


Shrewsbury
Leicester
Norwich
Yarmouth
Cardigan Bay
Hills
Warwick
Malvern
Worcester
Huntingdon
Leominster
Northampton
Stowe
Carmarthen
Monmouth
Oxford
London
Bath
Winchester
Brighthelmstone
Exeter
Bodmin
Isle of Portland
Isle of Wight
Lands End
Lizard P.
Marine Sand
London Clay
Plastic Clay & Sand
Chalk
Green Sand
R. Thames
North
South
Section of the Vale of Thames.

Plate 6.

An Outline Map of the Geology of England by R. Bakewell.

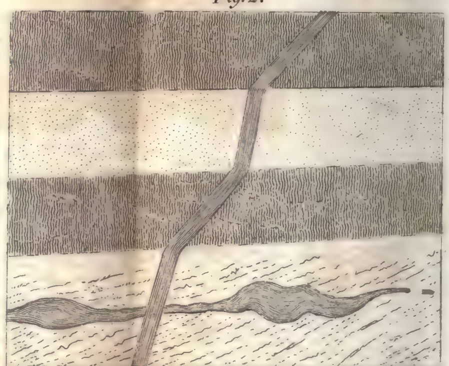
Plate 7.

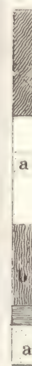


A SECTION OF THE STRATA THROUGH ENGL

Fig. 8.

Fig. 2.





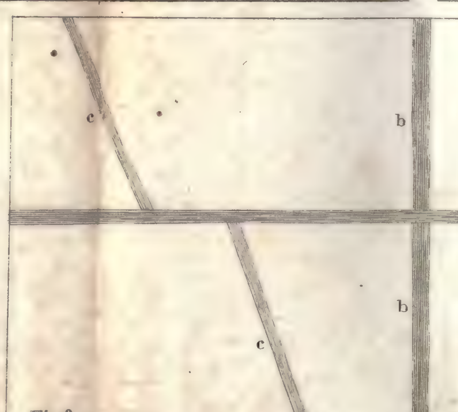
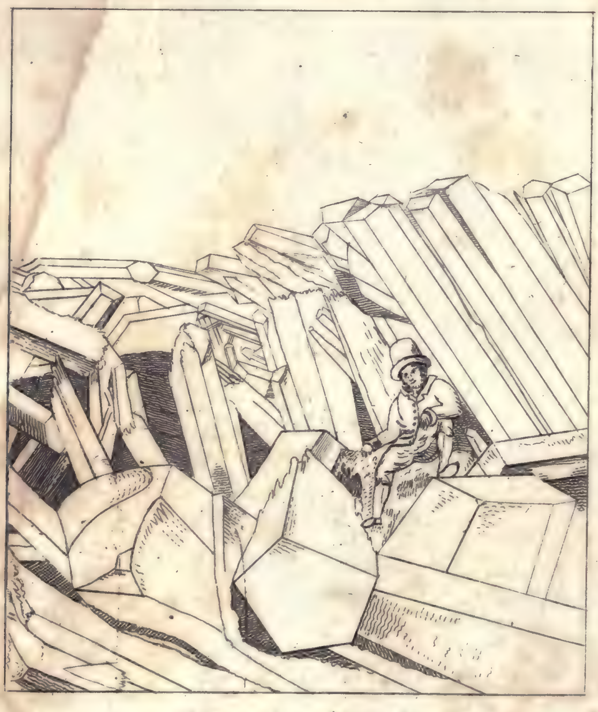


Fig. 3.



Columnar Trap. *Cader Idris.*

...FROM DURHAM TO CUMBERLAND BY R.BAKEWELL.

...9

Fig. 7.

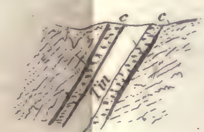


Fig. 6.

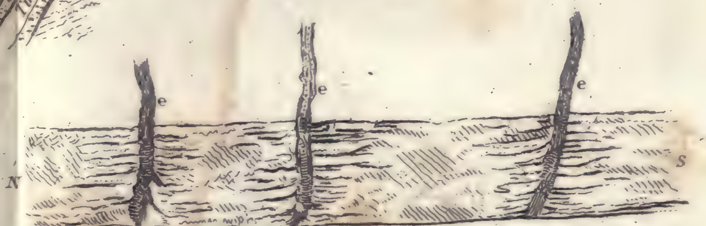


Fig. 5.

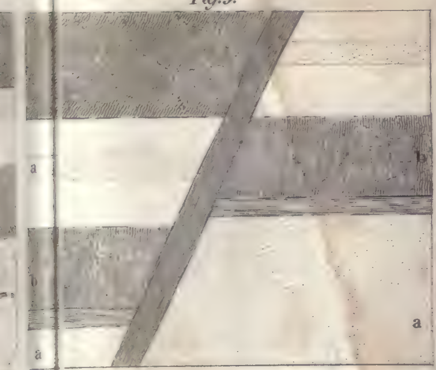


Fig. 4.

Plate 8.

LIVING ILLUSTRATION

Daggett & Ely Sc N. Haven.

F FOSSIL CONCHOLOGY &C.